MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

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Lieut.-General J. F. TENNANT, C.I.E., R.E., F.R.S., President, in the Chair.

The Rev. S. Runsie Craig, B.A., LL.B., F.S.S., the Rectory, Moville, Londonderry, Ireland; and
James Edward Keeler, B.A., Lick Observatory, San José, California, U.S.A.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election, the names of the proposers from personal knowledge being appended :—

John William Aldridge, 14 Mansford Street, Hackney Road, London, N.E. (proposed by Rev. E. Ledger);
Thomas William Brownell, 26 Lincroft Street, Moss Side, Manchester (proposed by Rev. W. H. K. Soames);
George Cumes, F.R.G.S., Principal of Huntingdon House School, Teddington (proposed by G. M. Whipple);
George Henderson, M.R.A.S., F.S.A.Scot., F.R.S.North. Antiq., Ovenden, Sundridge (proposed by J. C. Roger);
Frank Robbins, Clerk, 154 Oakley Street, Chelsea, S.W. (proposed by R. T. A. Innes).

Report of the Eclipse Committee of the Royal Astronomical Society, 1890 *March* 14. Drawn up by H. H. Turner, Secretary to the Committee.

No. II.

A. *General Account of the Expeditions of* 1889 *December* 22.

In the first Report, printed in the *Monthly Notices*, vol. l., No. 1, the arrangements for the two expeditions to be sent out by the Society were detailed, and a programme of operations was drawn up for the observers.

In continuation of that Report I have now to give an account of the conduct of the expeditions, and a preliminary statement of the results, reserving for a future Report the complete discussion of the photographs.

No material alteration was made in the programme adopted in the last Report. Mr. Taylor left Liverpool for Loanda by the Royal mail steamer "Bonny" on 1889 October 9, and arrived at Loanda on November 16. On November 19 he wrote to Mr. Common describing the voyage. A melancholy incident of that voyage was his interview with Commander Pullen, who was doing longitude work at Bonny, and who died a few days afterwards from fever. On December 23 a telegram was received from Mr. Taylor containing the single word "Zero," which, according to a prearranged code, signified that no results whatever had been obtained. It was, in fact, cloudy for the whole of totality. This telegram was communicated verbally to the Society on 1890 January 10. Mr. Taylor's detailed report is given below.

Father Perry, who took with him Mr. Rooney as an assistant, left Southampton on 1889 November 14, by the R.M.S. "Tagus." A letter to me, dated Barbados, 1889 November 28, was read to the Society on 1890 January 10, as follows:—

"H.M.SS. 'Comus' and 'Forward' were both at anchor in the roadstead on arrival of mail, and the instruments were at once transferred to the 'Forward.' During the voyage all our cases were kept with the mail bags, except the box containing chemicals, plates, &c., which was stowed in the front saloon. Mr. Rooney left this morning at 11 A.M., in H.M.S. 'Forward.' They are to take soundings on arrival to prepare us a snug berth. We are looking up tents, and hope to join the 'Forward' at Salut Isles on December 7, leaving a full week for erecting instruments, and another for rehearsals. I have given Mr. Rooney instructions about choice of site and foundations of instruments, and as 'Forward' takes cement and bricks, we hope to find things advancing on the 7th. . . . All are most kind and anxious to assist in every way."

One other letter was received from Father Perry, dated 1889 December 12. He says:—

"I wrote from Barbados up to date December 2. H.M.S. 'Forward' sailed on November 28, and soundings, pilot, &c., were all ready for us when we sighted the Salut Isles on December 7. H.M.S. 'Comus' anchors within less than half a mile of the shore so we are always well within reach of aid of every sort. The Governor of Cayenne had received the fullest instructions from his Government, and is anxious to render us every assistance The Commandant des Isles du Salut enters most fully into all our plans, and is most kind and attentive to our wants. Everything so far has been more satisfactory than we could have

hoped. The weather is magnificent, but terribly hot. We have chosen an excellent site on Royal Island, and erected four tents: two large tents for the instruments, and two bell tents, one for the empties, and the other for chronometers, theodolite, &c. Concrete foundations have been laid for the mirror and lens, and a firm bed for the seconds-clock. Mr. Common's instrument will rest on a bed of concrete that would be firm enough for a standard observatory; the nuts have been set this morning, and I hope to get the whole instrument in position this afternoon, with the exception of the mirror. Mr. Rooney's coronagraph is well mounted on a solid foundation, and I expect to get its position accurately this evening. Our photographic dark room is one of the convict cells, and when the carpenters have completed their work, we hope to have a most convenient room. At first we excluded the light very effectively, but the air was lost as well, and then lamps and candles refused to burn.

"The water supply is good, and we have fortunately found everything uninjured in the boxes already opened.

"I took two photographs yesterday and the plates showed no signs of frilling, in spite of the high temperature of the water. We have no ice here, but some may perhaps be procured from Cayenne. Mr. Rooney enjoys robust health, but I have had a very slight touch of fever, and am taking quinine and sulphur baths. We have excellent quarters in the military hospital, and all the officials on the island are devoted to our interests. I need scarcely say that Capt. Atkinson and the officers and men of H.M.S. 'Comus' could not be more kind or take a greater interest in the success of our observations."

On 1890 January 3, the following telegram was received from Mr. Rooney:—

"104 Corona American Perry dead dysentery."

The figures 104 are in the language of the cypher code prearranged for communicating results of the expeditions, which code is given below. The figures signify:—"Weather moderate, clouds; exposure with the lens successful, development not; exposure with the mirror successful, development not." It was rightly conjectured that the development was not attempted, owing to the illness of Father Perry; the plates were brought to England for development by Mr. Rooney.

The words *Corona American* signify that the Corona was generally of the same form as that shown in the American photographs of the Eclipse on 1889 January 1. The remaining words refer to the death of Father Perry from dysentery on December 27; his body was landed at Demerara on December 28, and buried by his old friend and pupil the Archbishop of Demerara. Mr. Rooney returned to England by the R.M.S. "Eden," bringing with him the instruments and plates (undeveloped)

taken during the eclipse. He called at the Royal Observatory, Greenwich, on 1890 January 21 and 22, bringing the plates, and notes &c. by the officers of H.M.SS. "Comus" and "Forward."

These notes were as follows :—

1. A Report by Lieutenant John F. Mills, R.N., showing the running of the driving clocks by the R.A. circles and a chronometer, on December 19–22. The driving clocks were apparently going well on the morning of the eclipse. Also a record of the temperature during the eclipse; remarks on totality, weather, &c.—(See below.)

2. The cards issued to the time-keepers. These are simply a series of bold figures, beginning at 135 and decreasing to 1. On the signal being given for totality, the observer at the chronometer counted backwards in a loud voice, beginning at 135 (135 seconds being the computed duration of totality). The recorders crossed out on these cards the number being called when an exposure was made or completed. There were three independent recorders to each instrument, and at least two of them agree in every instance, the third sometimes differing by 1 sec.

The records are as follows, the first number being always supported by two records :—

Lens.	*Mirror.*
Secs. Secs.	Secs.
130 (or 129) to 125	135 (One second)
	Secs.
120 to 111	123 (or 124) to 119
106 (or 105) (One second)	107 to 97
100 to 90	86 to 66
70 to 51	51 to 11
45 (or 44) to 7	And after totality, marks representing instantaneous photographs at 8, 30, 60, 90, 120, 150, and 189 (or 190) seconds after totality.

3. Officers' Reports and drawings of Corona, notes of which are appended.

The plates were immediately taken by me to the Society's rooms and deposited with Mr. Wesley. They were all packed together and hermetically sealed. They were removed by Mr. Common to Ealing, where he developed the plates taken with the 20-inch mirror. The others were handed over to Captain Abney, who developed them. The following brief description of the plates obtained was drawn up by Mr. Wesley :—

Photographs taken with 4-inch Lens.

No. 1. (Exposure 5 sec., but with reduced aperture; equal about to $\frac{1}{4}$ sec. full aperture.) Very little Corona, but

prominences on E. side very well shown and in perfect focus. Plate absolutely clear and free from spots.

No. 2. (Exposure 10 sec., with reduced aperture; equivalent to $\frac{1}{2}$ sec. full aperture.) Three or four separate exposures overlapping: in all other respects same as No. 1.

No. 3. (Exposure 1 sec., full aperture.) Clear plate without spots; shows same prominences as 1 and 2, but a little elongated through a slight shift. Corona can be traced to rather more than $\frac{1}{4}$ diameter from limb.

No. 4. (Exposure 20 sec., full aperture.) Corona can be traced to $\frac{1}{2}$ a diameter from limb; shows some detail, but interfered with by white spots; prominences on E. limb only. Corona near edge of plate.

No. 5. (Exposure 10 sec., full aperture.) Greater extent of Corona, but plate spoiled through a considerable shift. Shows prominences on E. limb and trace of one on W.?

No. 6. (Exposure 40 sec.) On the whole, the best of the plates. Corona dense, extending to not quite a diameter from limb: coronal details can be made out, but they are not very definite. Chromosphere showing strongly on W. limb; reversed on most intense part.

Photographs taken with 20-inch Mirror.

No. 1. (Exposure 1 sec.) The merest trace of the limb.

No. 2. (Exposure 5 sec.) Corona extends nearly $\frac{1}{2}$ diameter from limb in some parts. Very thin negative: shows a little detail to the S.; in other places much interfered with by spots. Very faint trace of prominences on E. limb.

No. 3. (Exposure 10 sec.) Corona extends $\frac{3}{4}$ diameter from limb to E. and N. Thin negative; extremely spotty; shows some details at poles very well. Prominences on E. limb seem *reversed* in a very singular manner.

No. 4. (Exposure 20 sec.) Corona extends rather further than in No. 3, but the plate is so much spotted and scratched that less detail is shown. Prominences on E. limb and lower parts of Corona to E. and W. are *reversed*, yet the negative is not very dense.

No. 5. (Exposure 40 sec.) Corona possibly extends nearly a diameter from limb, but plate fogged and *very much* spotted; detail scarcely visible. Prominences on both limbs and lower portion of Corona sharply reversed, but limb very clearly defined.

No. 6. (Instantaneous, taken 8 sec. after totality.) Shows portion of reappearing crescent, sharply reversed. The whole limb of Moon visible, with trace of Corona.

Nos. 7–12, taken 30, 60, 90, 120, 150 and 190 seconds after totality, show the reappearing crescent sharply reversed and doubly reversed, but no trace of Corona or Moon's dark limb.

Captain Abney writes on January 29 :—"I finished developing the [lens] plates this evening. To begin with, the plates have suffered slightly from having been repacked with damp paper *in contact* with the films, and as a consequence the scales *on the* plates are useless. I developed the 20-second photograph first, and found the scale bad, so I developed fresh scales exposed on the same *batch of* plates with each of the remaining Corona pictures, so they are all right for measuring. The plates are rather spotty, owing to the repacking. They ought to have been repacked as sent out. The plates which I had at home not tinned up, but in grooved boxes, are spotless.

"Now for the photographs themselves :

No. 1. (=$\frac{1}{4}$ sec.) Very good; prominences sharp and very little halation; very good for drawing and for measuring the brightness close up to the limb.
No. 2. (=$\frac{1}{2}$ sec.) Three distinct images of the limb; very useful for showing the inner Corona.
No. 3. (1 sec.) Good; less extension than in No. 4.
No. 4. (10 sec.) An excellent photograph. Not so much extension as in No. 6, but by reflected light very nearly so.
No. 5. (20 sec.) The clock evidently went wrong in this: a blurred image, but useful for drawing.
No. 6. (40 sec.) I should say the full Corona developed. Evidence of a very bright sky as well.

"From a casual examination I should say that the Corona close to the limb is about 200 times brighter than the Corona $\frac{1}{2}$ diam. away. There will be lots to do in the measurement which will make this eclipse very valuable, I think, though the photographs are not as good technically as they might have been. There is very little structure in the Corona."

Mr. Common remarks :—"I am very strongly of opinion that the mirror was dewed." This seems to be very probable. The cotton wool placed over the mirror in repacking was found quite damp when the hermetically sealed tin case containing it was opened at Greenwich, and Mr. Rooney says that it was almost impossible to keep things dry. The mirror was seen to be dewed on opening the telescope before the eclipse and was turned towards the Sun at once; but it is very doubtful whether its reflecting surface would even in an hour absorb enough heat to dry off the dew. Father Perry, who had charge of the mirror, was not able to come to his instrument till late, and it is quite possible that the dewed state of the surface was overlooked. The conspicuous failure in photographic power shown in the short-exposure plates with the mirror, is strong evidence of an anomalous condition of the surface.

The *objects of the expeditions* were stated in the last Report to be threefold :—

I. To detect any possible changes in the Corona during the $2\frac{1}{2}$ hours that elapse between the dates for totality at the respective stations.

The failure to obtain results at the South African station disposes of this point.

II. To photograph the coronal extension as far as possible.

It cannot be said that any definite conclusion has been arrived at with regard to the extension. It is almost certain that for some cause the 20-inch mirror was not efficient on the occasion of the eclipse, and it is probable that it was dewed. With an effective aperture of 15 inches the short-exposure plates should have shown much more if the mirror had been in its normal state. Hence the failure to photograph the Corona more than about a diameter from the limb in 40 seconds cannot be taken as evidence against the possibility of photographing "the extension" in the future.

III. To determine the photometric intensity of the Corona.

Captain Abney's care in developing new plates with standard squares on them at the same time as the eclipse plates has rendered this feasible. He has expressed his willingness to undertake this part of the work, and it only remains to place the plates in his hands for the purpose.*

I would suggest also that Mr. Wesley be asked to make a drawing of the Corona from the two series of plates.*

Some photographs were also taken with the mirror after totality at the suggestion of Captain L. Darwin and Dr. Huggins, and are referred to above. I would suggest that Dr. Huggins be asked to examine these.*

The remaining sections of this Report are as follows :—

B. Mr. Taylor's Report.

C. Mr. Rooney's Report, which he has kindly prepared for us, although he did not originally undertake work for the Society.

D. A summary of the notes made by the naval officers, &c.

E. The cypher code referred to above.

B. *Mr. Taylor's Report.*

The expedition to South-west Africa for observing this eclipse left Liverpool in the Royal Mail steamer "Bonny," of the British and African Steam Navigation Company, Limited, on October 9, and arrived at St. Paul de Loanda on November 16,

* Recommended to the Council and adopted.

touching at Grand Canary, Sierra Leone, and other important places on the voyage.

Immediately on arriving at Loanda I placed myself in communication with Mr. Edward Bannister, the Acting British Consul for the province of Angola, and by his exertions it was arranged to land the instruments without examination by the Custom House authorities. His Excellency the Governor-General of Angola very much facilitated the arrangements in Loanda, and very kindly offered his services if he could in any way assist the expedition.

The instruments were landed at Loanda on November 18 and stored in the warehouses of Messrs. Newton, Carnegie & Co., pending the arrival of the gunboat to convey them to the eclipse station. It had not been decided before the expedition left England which ship of the Cape Squadron could be sent to assist at the eclipse station, but while at Bonny I heard from the late Commander Pullen, R.N., then with the gunboat "Alecto" engaged in determining the latitude and longitude of Bonny, that H.M.S. "Archer" would be sent to assist the expedition. Admiral Sir Richard Wells also telegraphed from the Cape to Loanda telling me I might expect the "Archer" on December 10. The eclipse station at Cape Ledo being in an unexplored district, where the natives were hostile, according to the Portuguese authorities in Loanda, and where great difficulties in landing were expected owing to surf, I did not consider December 10 would allow sufficient time for preparations, and telegraphed to Admiral Wells to that effect. He immediately ordered the gunboat "Bramble" from Fernando Po to Loanda to assist the expedition, and hurried on the "Archer" from the Cape of Good Hope with the tents and stores. The "Bramble" arrived at Loanda on December 2, and the "Archer" on December 4. Commander Ferris of the "Archer" immediately placed either ship at the disposal of the expedition. After consultation it was decided that the "Bramble" should assist, and the tents and instruments were at once placed on board. Early on the morning of December 5 the "Bramble" started for Cape Ledo, anchoring in Mastote Bay under shelter of the Cape late in the same afternoon.

Next morning Lieutenant and Commander Langdon of the "Bramble" and myself explored the district round Cape Ledo, but could not find any trace of "Antigas Factories," which are marked on the chart as being exactly on the central line of the eclipse. No one in Loanda had heard of these factories, and we found that no such place is in existence near Cape Ledo. We were very fortunate, however, in finding a splendid station on the plateau near Cape Ledo, landing and access to the plateau being comparatively easy at this place, although quite impossible at any other point for at least ten miles north of the Cape. The latitude of the station was ascertained, the sites of the instruments fixed, and the ground cleared immediately.

The landing of the instruments was scarcely interfered with by the surf, thanks to the surf-boat kindly lent to the expedition by the Governor-General of Angola, and everything had been safely carried to the station, about 400 yards inland, by December 10.

Concrete blocks were set in the loose sandy soil to serve as supports for the bases of the instruments, and the erection of the photoheliograph with the 4-inch lens at once proceeded with. It and the 20-inch reflector were erected by December 14, the weather up to this time being very unfavourable for astronomical work. During the next week the weather was generally cloudy, but the few clear evenings enabled the necessary adjustments to be made and the focus to be accurately fixed by means of star photographs with each instrument.

Lieutenant and Commander G. F. Langdon took charge of the 20-inch reflector; Chief-Engineer W. Lonnen, who had some previous experience in photography, undertook to photograph the Corona with an ordinary quarter-plate camera; while the photoheliograph with the 4-inch lens was reserved for myself. Dr. Beatty had charge of a 3-inch telescope (kindly lent by Professor David P. Todd, of the American Expedition, at Cape Ledo) and undertook to make a drawing of the Corona. Lieutenant G. W. W. Dawes and Chief-Gunner Looman undertook to call the time during totality. Complete rehearsals of the whole of the operations of the eclipse were held on the four days preceding the day of the eclipse.

Experiments were made during the four days before the eclipse with the different plates and developers sent out. On the whole Mawson and Swan's extra sensitive dry plates were found to give the best results with all the developers tried, and I decided to use these plates for the photographs with the mirror. Successful pictures for orientation were obtained at 3 o'clock on December 21.

The evening of December 21 was clear, and star photographs were taken as a final check on the focussing of the instruments. These were very satisfactory. The sky clouded at about 10 o'clock on the night of December 21, and remained cloudy during the whole of the next day. At 10.45 A.M. on December 22, a slight shower of rain rendered it necessary to cover up the instruments. Towards noon the sky improved, but approaching the time of first contact the clouds again thickened. At $1^h\ 29^m\ 35^s$ P.M. local mean time, I noticed through a break in the clouds that first contact had taken place. As totality approached the Sun was seen through occasional breaks, but never for more than half a minute. Clocks were wound and started, caps and stops removed, and everyone was ready 15 minutes before totality. Thick clouds now covered the Sun, while the darkness increased rapidly, "two or three rapid bounds of darkness" being noticed.

When the eclipse became total the clouds round the Sun assumed a leaden colour, and a patch of blue sky to the east

became purple, but at no time was the darkness very intense. The clouds near the horizon reflected sufficient light to enable the chronometer minute and hour hands to be seen at 8 feet distance, and the second hand to be seen at 3 feet. The white tents of the American camp about half a mile distant were distinctly visible. Before totality the wind had entirely ceased, but a distinctly cold wind blew from the south-west during totality. Lieutenant Dawes noticed just at the end of totality that "the western sky seemed very dark, and after a few seconds it suddenly brightened, the darkness seeming to pass away across the eastern sky." No trace of the Corona was seen and no exposures were made with either instrument during totality. The end of totality was noted owing to the sudden breaking out of the light, but the Sun itself was not seen for 20 minutes after that time.

Immediately after the eclipse the instruments were dismounted, packed, and conveyed on board the "Bramble," which left for Loanda early on December 23, arriving there in the afternoon. The return voyage to Liverpool was made in the S.S. "Cameroon," which left Loanda December 27, and arrived in Liverpool on February 20.

The officers and crew of H.M.S. "Bramble" worked in a manner beyond all praise during the whole of the operations at the eclipse station.

The courtesy and assistance of His Excellency the Governor-General of Angola have already been referred to. The best thanks are also due to Mr. E. Bannister, the Acting British Consul at Loanda, and to Messrs. A. Nightingale and W. S. Brock (of Messrs. Newton, Carnegie & Co.), for their kindness and assistance at that place; also to Commander Ferriss of H.M.S. "Archer" for his valuable assistance at Loanda. I must also recognise the kindness and generosity of Messrs. Elder, Dempster & Co. and their agents along the coast for their kind offices on the voyage to Loanda and back.

A. TAYLOR.

Ealing:
1890 *March* 11.

C. *Mr. Rooney's Report.*

In obedience to instructions received from the Committee of the Royal Astronomical Society, the Rev. S. J. Perry and his assistant, Mr. J. Rooney, sailed from Southampton on November 14 in the R.M. ship "Tagus," Captain Brander, for Barbados, en route for the Iles du Salut, to observe the total eclipse of the Sun on the morning of December 22. After a fair passage we reached Barbados at 6 A.M. on November 26. Here we found H.M. ships "Comus" and "Forward," under orders from the Admiralty to conduct us to the place of observation. At 9 A.M. Captain Atkinson and Commander Gray came on board the "Tagus," and after a consultation it was arranged that Commander Gray should take

Mr. Rooney and the instruments, tents, &c., on board the "Forward," and sail on the 28th to the Iles du Salut. The Commander was instructed to take soundings near the islands so as to secure safe anchorage for the "Comus," and come out with a pilot to meet that vessel on her arrival, which was fixed for December 7. Mr. Rooney was to select a site for observation, and get the instruments landed. Accordingly on the 28th, at 11 A.M., the "Forward" sailed, and after a rough passage the islands were sighted on December 5 at 10 A.M., and at 4 P.M. the vessel was anchored about a quarter of a mile from the main island. The Iles du Salut are a group of islands off the coast of French Guiana, about twenty-two miles from Cayenne, and twelve miles from the mainland. They are used by the French as a penal settlement for convicts from their colonies. The group consists of three islands, the largest of which is Royal Island, on which the commandant and chief officials reside. Here also are two large hospitals, one for the military, the other for the convicts. There are 700 convicts on this island, 150 being French, the rest Arabs, Mahometans, and Chinese. They are guarded during the day by 40 warders, who always carry loaded revolvers, and at night by 60 infantry. The other two islands are "St. Joseph's," where political prisoners are detained, and the "Devil," where lepers reside. These latter are supplied with food twice a week, and receive an occasional visit from the doctors.

Soon after the "Forward" had anchored, Dr. G. Dufour came on board, and then Commr. Gray and Mr. Rooney went to pay a visit to the commandant, and were most cordially received. He informed us that orders had been sent out by the French Government to give the observers every assistance possible. He therefore put the convicts' labour at our disposal, and had already prepared four rooms for us in the officers' quarters of the military hospital, a very fine building. On the following day Mr. Rooney discovered an excellent site for the observatory in a disused garden, with a clear horizon from N. to S.S.E., and protected on the W. and S.W. by a wall. On the morning of the 7th Mr. Rooney and Dr. Jacks, of the "Forward," landed on the Royal at 5 A.M., and from the spot selected the previous day they sighted the pole star, and took the position of the Sun at rising, and with the help of a compass marked the cardinal points on the ground by sinking stones into it. This precaution was taken to prevent the marks being washed away by the heavy rains. As the site promised to be in every way most satisfactory, the instruments were landed, and the "Forward" set out at 9 A.M. with a pilot to meet the "Comus," which was sighted at noon, and brought to a safe anchorage under the lee of Royal Island, about half a mile from the shore, by 3 P.M. Father Perry and Captain Atkinson landed at 4 P.M., and were received at the landing-place by a bodyguard, which escorted them to the commandant's residence. The commandant, M. Ferdinand Leloup,

received them most kindly, and repeated the instructions received by him from the French Government. The site chosen for the observatory was then visited, and the rooms at the hospital; and Father Perry expressed his great satisfaction with both. On his requesting the use of some place that would serve as a photographic dark room, a condemned cell was at once placed at his service. On Monday morning, December 9, Lieutenant Thierens, with a party of about twenty men, landed, and with the assistance of the convicts carried the instruments, tents, &c., to the chosen site, which was about 200 feet above sea level. By night all the tents were erected, and the foundation for the 20-inch mirror was started, and all the photographic materials were unpacked and arranged in the condemned cell. Father Perry gave a lecture on Solar Eclipses, which was illustrated by slides projected on the screen by means of a magic lantern. This took place on board the "Comus," in the presence of the officers and men of the two ships, and at the end he read out the names and duties of those who had kindly volunteered their services during the eclipse. On the morrow, the 10th, the "Forward" sailed for Bermuda. The foundations for the stand of the 4-inch lens and the seconds clock were ready by the 12th, and the stand and base-plate were mounted.

In order to fix the polar axis with the greatest possible accuracy, Mr. Rooney, assisted most ably by Lieutenants Thierens and Mills, made use of the following method. Instead of sighting the pole star by means of the sockets alone, which carry the polar axis, a piece of brass was inserted in each of them, one with a small round hole, and the other with a cross cut out of it. At its culmination the pole star was sighted through these two apertures, and the instrument moved until the star was visible in the centre of the cross. The instrument was next adjusted for latitude, and as soon as the exact position was obtained, cement was placed round the back leg of the stand, which had been fixed in the foundations in a hole four inches deep. After allowing a night to intervene, the instrument was again tested for latitude and level, and found to be quite accurate; hereupon the two fore legs were secured with cement, and a covering of soil, about twelve inches deep, was placed round the legs to prevent displacement. The instrument was then completely mounted; but it was found that the slides and shutter had warped and would not work. This defect was soon remedied by the carpenter, and on the night of the 14th some trial photographs of the stars were taken. After four plates had been exposed, it was found that the brass circle, for clamping in declination, was broken. This stopped the work for the night at 11 P.M.

On Monday, 16th, at 3 P.M., the clamp was repaired and the instrument remounted, and the first full rehearsal fixed to take place at 4.30 P.M. The instruments to be used were a silver-on-glass mirror, 20 inches aperture and 45 inches focus,

by Mr. A. A. Common, F.R.S., and a lens 4 inches aperture and 5-foot focus, the property of Captain Abney, R.E., F.R.S. Father Perry took charge of the former, and Mr. Rooney of the latter. The observatory camp was an oblong, some 30 yards by 20. In this the instruments were placed diagonally, 15 yards apart, with the seconds clock midway between them. The Simms transit theodolite, from Stonyhurst Observatory, was used by Lieutenant Mills to get the latitude and longitude of the station.

The programme drawn up by the Solar Eclipse Committee of the Royal Astronomical Society was as follows:—With the mirror five exposures were to be made of 1, 5, 10, 20, 40 seconds respectively, with others at discretion. With the lens six exposures were to be made, two with 1-inch diaphragm, of 4 sec. ($=\frac{1}{4}$ sec. full) and 8 sec. ($=\frac{1}{2}$ sec. full), and four with full aperture of 1, 5, 15, 40 seconds respectively; two others might be made at discretion.

At the rehearsals, as on the day of the eclipse, there were four assistants at each instrument, three officers to note down the exact second called by the timekeeper when each plate was exposed and when the exposure was completed, and one first-class petty officer to give out the plates in order, and after exposure to place them in the receiving dark box. The time-keeping was entrusted to Dr. Axford, R.N., and the yeoman of the signals. It was the duty of the former to count seconds from a chronometer for three minutes before totality, and immediately totality commenced to give the signal to the latter, whose duty it then was to set the clock going and begin to count the seconds in a loud voice, beginning with 135 and counting backwards to 0. The structure of the Corona was to be observed by Captain Atkinson with a small telescope, kindly lent to Father Perry by General J. F. Tennant, R.E., F.R.S., whilst a similar observation was to be made by Lieutenant Thierens with the naked eye.

At each instrument two blue-jackets were stationed with lamps, and two sentinels were placed on guard with strict orders not to allow anyone to enter the camp during the rehearsal. Chief-Engineer Ellis was in attendance, to offer his services in case they were needed. At the first rehearsal great confusion prevailed, chiefly on account of the inaccuracy in counting the seconds. This was partly owing to the fact that a deck watch had to be used, as the seconds clock was found to have been seriously damaged during the voyage. After a second lecture which Father Perry gave that evening he pointed out improvements which might be made on the first rehearsal. On the 17th a second rehearsal took place, but although the seconds clock was in use it was not in good working order, and the rehearsal was not a success. On the 18th the rehearsal went off very smoothly, the seconds clock being in very good order. As it was desirable to hold a rehearsal as far as possible under the circumstances which would prevail during the eclipse itself, another was

held on the 19th at 6 P.M. in twilight, and no confusion was caused by the darkness. At 9 P.M. the same evening rain began to fall in torrents, and continued all night, so that no trial photographs could be taken. On the 20th at 9 P.M. the stars shone out most brilliantly, and Father Perry decided to remain in the observatory all night to take trial photographs. On developing the first plate exposed with the mirror it showed that the instrument was very much out of focus, but after exposing and developing nine other plates the focus was secured. The sky then became clouded at 2.30 A.M., so Lieutenant Thierens and his men returned to the "Comus" for the night. As Father Perry thought that it might clear up again, and he wanted to get a few more photographs if possible, and as he wished to sight the position of the Sun at its rising, he lay down in his hammock under one of the bell tents instead of going to his quarters at the hospital. Mr. Rooney did not like the idea of sleeping there, so he walked about the camp. It is thought that Father Perry got a chill on this occasion, for the dew falls very heavily during the night on the Salut Isles. At 5.45 A.M. Father Perry got up and prepared to take the Sun's position, in which he succeeded about 6 A.M. The party from the "Comus" arrived at 6.45 A.M. To secure the orientation of the plates photographs of the Sun were taken by both instruments, using a pinhole aperture with the telescopes clamped and clocks not driving, at intervals of a hundred seconds, on the same plate. It had been arranged that these photographs should be taken on the days before and after the eclipse, at the local time at which the eclipse took place. Two plates were exposed at each instrument, and after the rehearsal, which took place at 7.30, these plates were developed, and it was found that the two taken by the lens were good, but those taken by the mirror were a failure, as no trace of an image appeared on the plates, owing, it is thought, to the pinhole aperture being too small. It was decided that while the astronomers were taking a little repose a new diaphragm with a larger aperture should be made by the engineer. This was ready at 3 P.M., when a successful photograph of the Sun was taken with the mirror. Further arrangements for the morrow's obser vation were then made, and the instruments were prepared to take photographs of the stars after dark, but the sky was overcast, with heavy rain, so after the chemicals, &c., had been got ready in the dark room, and everything was complete and in good order for the 22nd, the astronomers retired to their quarters for the night.

At 3.30 A.M. Mr. Rooney hearing Father Perry moaning entered his room and found him in great pain. He gave him a dose of some medicine which they had brought with them, and this seemed to give him some relief. Before Mr. Rooney left Father Perry requested him to send a blue-jacket to assist him over the rough road to the observatory.

At 4.45 Mr. Rooney started for the observatory, to get every-

thing ready and put the plates into the slides. Eight of Captain Abney's specially prepared plates were placed in two single dark slides, four in each, for the lens, and twelve of Ilford's ordinary plates were placed in six double slides for the mirror. Numbers to indicate the order of exposure were marked with a writing diamond on the left-hand top corner of each plate. Each slide was put in a separate black bag, marked with a bold white number corresponding to that of the slide. These bags were then put in zinc-lined boxes, one for each instrument, which were then carried to the camp.

At 6 A.M. Lieutenant Thierens and his men arrived. The officer was informed of Father Perry's illness and request, so a man was sent off at once. The Sun rose in a clear sky, but at 7 o'clock all looked very black, and at 7.20 a heavy shower of rain fell, and Mr. Rooney got both instruments covered with tarpaulins, but left them in position, and allowed the clocks to run. The shower over, he had the tarpaulins removed, and looked to the lens and saw that both instruments were still in position.

As Father Perry had not yet arrived, Mr. Rooney suggested to Captain Atkinson that as Lieutenant Thierens had assisted Father Perry at the mirror during the trials, he should take charge of that instrument. This arrangement was agreed to, but whilst a consultation was taking place to settle which exposures it would be best to secure, Father Perry was seen coming down the hill leaning on the blue-jacket. On his arrival in the camp he asked Mr. Rooney if everything was ready, and being told that all was quite ready, he walked round to see that every man was in his place, and at the appointed time gave the signal to wind clocks, &c.

The sky brightened up a little, and there was a large patch of blue near the Sun; a few minutes later the Sun appeared, it being then a little more than half eclipsed, and about seven or eight minutes before totality commenced the Sun was well out into the blue patch. The writer of this report will now confine himself chiefly to what occurred at his own instrument.

I watched the image on the ground glass, and saw that it was beautifully sharp and clear.

About 30 seconds before totality I told Mr. Davis to put in the inch diaphragm; accordingly the dew cap was removed and the diaphragm inserted, then the dew cap was replaced. The dew cap was 12 inches long. The reason why I did not get the diaphragm inserted sooner was because on several former occasions I had put it in before running the instrument on the Sun, in order to protect the lens, and I always found condensation on the lens when the diaphragm was removed. I then put in the slide and removed the ground glass, and awaited the signal to begin. After the second exposure, I waited a second or two until the instrument got steady after the removal of the diaphragm, and this precaution I adopted each time after changing

the position of the slide. I had just closed the shutter after the 40 sec. exposure on the sixth plate when the signal for the end of totality was given. I had thought of exposing the seventh plate very rapidly, but finally decided that, as the slide had been so carefully protected from the light so far, it would be better to run no risk from the bright sunshine, and therefore I at once removed the slide, and put it into its black bag, and then into the zinc-lined box. Had the totality lasted 135 seconds, as I expected, I should have been able to expose the two additional plates, but as it lasted only 129 I was just able to secure the six exposures on the programme. The sky round the Sun was clear some seven or eight minutes before and after totality. I noticed that the Corona stood out magnificently, and the prominences were very marked. I saw at once that it was very much like the American one of January 1, 1889, a photograph of which I had seen, and a positive of which was projected on the screen during the lecture on the "Comus." *Jupiter* and *Mercury* were quite visible during totality.

At my instrument lamps were not needed at all, as I had previously marked the slides with bold labels, on which I had marked the number of the plate and the amount of exposure. When the eclipse was over, the plates were taken to the condemned cell and locked up.

At the end of the observation Father Perry walked over to me and asked me if everything had gone right at my instrument. I replied that everything had gone on most satisfactorily. He then said, "This is the most successful observation of the kind that I have ever had anything to do with." He then asked Captain Atkinson to get the men to give three cheers for the successful observation, and three hearty cheers were given. He said, "I cannot cheer," but he waved his helmet.

From the moment he entered the camp until the observations were all over he seemed quite himself, and everybody hoped that he was not so ill as was feared; but it was with great difficulty that I got him up the steep hill back to our quarters. Frequently on the way he spoke of the providential manner in which the sky cleared and enabled us so successfully to photograph that for which we had travelled so far. He considered the toils and fatigues well repaid by the magnificent sight we had just beheld. When we reached the hospital he was quite exhausted. I asked the resident doctor to come and see him. He said he was very feverish and very much fatigued. The doctor told him to remain in bed and await some medicine.

Father Perry told the marine to pack up all his things, and he wished me to go on board the "Comus" to take some rest to be ready for the work of the morrow; he also wished me to ask Captain Atkinson that a boat might be sent for him at five o'clock that evening, and a man to help him down. All was done as he wished, and at 5.45 P.M. he arrived on board the "Comus." He was met by Dr. McSwiny, the staff surgeon of

the "Comus," who immediately reported to Captain Atkinson how serious the case was. The next morning it became clear that he was suffering from the very worst form of dysentery. I went to his cabin at 6 A.M., before starting for the observatory, when he told me to get the plates which had been exposed the previous day put into the zinc case and sealed up, as we should not develop them at the islands. I went on shore, and with the assistance of Lieutenants Thierens and Mills got both instruments ready to take the pinhole photographs, but the sky was overcast the whole morning. I reported this to Father Perry on my return, and he decided to dismount the 4-inch lens and to leave the 20-inch mirror standing until Tuesday morning, to make another attempt to secure a pinhole photograph. Meanwhile the doctor had pronounced Father Perry's life to be in danger, and the captain and doctor both thought it best to dismount the mirror and get everything packed and on board that day, and to start next morning, the 24th, with all despatch for Demerara. Father Perry assented to this, and additional help was sent on shore, and by 6.30 P.M. everything was safe on board. The next morning was overcast with rain, so that no photographs could have been taken, even if the instruments had been left standing. Father Perry had so bad a night that the order to sail was cancelled.

The weather on the 25th was fine but cloudy, so that no photograph could have been taken. Father Perry was a little better, but it was a very quiet Christmas Day for all on board. There was a piano in the ward room, but it was never touched during Father Perry's illness. The captain and Dr. McSwiny were anxious to get away, for there were men down with the same malady, and many others more or less unwell. Father Perry was consulted, and he consented to be put in a cot and incur the additional risk of sea-sickness in order to reach the Bishop and his confrères in Demerara. The Abbé and Commandant boarded the "Comus" to say good-bye. So on Thursday morning a start was made for Demerara. Father Perry passed a quieter day. Being asked by me if he felt the motion of the ship he replied that he was very comfortable. Towards night he grew worse, and Dr. McSwiny and Dr. Axford divided the night watch between them. In fact, they were unremitting in their attention. The night and day were divided into watches of four hours each, which were taken by the two doctors and myself. During my watch on Friday morning Father Perry gave me instructions to make out the telegram to be sent to Greenwich. He also wished me to take charge of everything after his death, and to hand the results of the expedition to Mr. Turner, the Secretary of the Solar Eclipse Committee. At 3.35 P.M. he lost consciousness, and became rapidly weaker, and peacefully passed away at 4.20 P.M. on Friday, the 27th. The body was carried by six marines to the bridge till the coffin was ready, in the cot in which he died, covered with a Union Jack.

At 10 P.M. the coffin was ready, and he was laid in it; his face quite calm and white, as if he was asleep. The coffin was left on the bridge. Father Perry died about seventy miles from Demerara, lat. 6·56 N., long. 56·50 W. At 3.30 on Saturday morning, 28th, we anchored two miles outside the lightship, which is itself twelve miles from Georgetown. The water being shallow, the "Comus" could get no nearer. Captain Atkinson sent a boat to the lightship to inform them of Father Perry's death, which they were to signal to the shore, and warn them to make arrangements for the funeral. Lord Gormanston, the Governor, with Bishop Butler, had met Father Perry in Barbados, and wishing him to lecture at Georgetown, had promised to send a steamer out as soon as the "Comus" was signalled. Before the lightship had received Captain Atkinson's message it had signalled the arrival of the "Comus," but owing to the mist it was unable to send the news of Father Perry's death. In the meantime his Excellency the Governor had sent a steamer, with Lord Gormanston's private secretary, Mr. J. F. Rawlinson, and Lieutenant Lingham, the harbour-master, aboard.

The steamer arrived at 9.30, and came as close as possible. At ten the captain ordered all hands on deck, and the same six marines who had carried the body before lowered it into the boat amid the solemn tolling of the ship bell. Father Perry had been a great favourite, and all on board seemed to feel his death very much. On the evening on which he died one of the blue-jackets came to me to say he was deputed by the other men on the lower deck to say how deeply they all felt his death. At 10.30 we steamed to Georgetown, and the "Comus," with her flag half-mast high, started for Barbados. On reaching land we found the Governor and the Bishop waiting to receive Father Perry, still ignorant of the sad reality. There was still some difficulty in arranging the funeral owing to objections raised by the officer of health; but it was finally settled that the body should be taken to the cathedral as soon as the grave had been prepared, and after a short service there to be carried at once to the cemetery. The Bishop received the body at the cathedral at two, accompanied by all the clergy. At 2.30 the cortège started. The body was carried to the hearse by six policemen, who walked by it to the grave. They were in charge of Inspector Gallagher. The Governor and his private secretary were present at the funeral. The prayers at the grave were said by the Bishop; the body of Father Perry was lowered into the grave at 4 P.M., December 28, 1889.

I sailed from Demerara on board the R.M. ship "Eden" on January 3, and arrived at Barbados on January 5, where I found the instruments, &c., which had come on in the "Comus." I left Barbados on January 6 in the R.M. ship "Medway," Captain Gillies, and arrived at Southampton on Saturday, January 18, and London January 20, and on January 22 handed to Mr. Turner the plates exposed, along with Father Perry's rough notes.

The greatest possible praise is due to Captain Atkinson and his officers and men for the hearty, earnest manner in which they threw themselves into the spirit of the expedition. Captain and officers were constantly inquiring if there was anything they could do to make us more comfortable and render the expedition a grand success. Lieutenant Thierens and his men deserve great credit for the able and cheerful manner in which they carried out each task that was entrusted to them. During Father Perry's illness on board the "Comus" the care of the doctors was most constant, and everything that it was possible to do for him was done.

I also wish to return my sincere thanks to Commander Gray, his officers and men, for the many acts of kindness I experienced at their hands during my stay on H.M S. "Forward."

J. ROONEY.

Stonyhurst College Observatory:
1890 *March* 10.

D. *Naval Officers' Reports, Notes, &c.*

(α) *Position of the Spot from which the Eclipse was observed:*

Long. $3^h\ 30^m\ 21^s$ W. or $52^\circ\ 35'\ 15''$ W. } Lat. $5^\circ\ 16'\ 45''$ N.

Observer: Lieutenant J. F. Mills, of H.M.S. "Comus."

(β) *Time of commencement of Totality.*

$7^h\ 49^m\ 52^s{\cdot}5$, Local Mean Time.
Duration of Totality, 129 secs.

Observer: Lieutenant J. F. Mills.

J. K. Watson marks on a time-card the second numbered 6 as end of totality, 135 being the beginning.

The signalman similarly marks the second 9.

Mr. J. R. Hind, of the N.A. Office, kindly supplied the following equations for the neighbourhood of Cayenne:

$$\cos\omega = -0{\cdot}79283 - [1{\cdot}98752]\sin l + [1{\cdot}73085]\cos l\cos(\lambda + 132^\circ\ 5'{\cdot}7)$$

$$t = 1^h\ 16^m\ 56^s{\cdot}4 \mp [1{\cdot}83514]\sin\omega - [3{\cdot}32747]\sin l - [3{\cdot}86213]\cos l\cos(\lambda + 74^\circ\ 18'{\cdot}5).$$

where

l = Geocentric latitude of point.

λ = longitude E. from Greenwich (here −).

t = G.M.T. of beginning or end of totality.

With these equations and position given in (α) the Local Mean Time for commencement of totality is $7^h\ 49^m\ 57^s$, and duration 135^s.

(γ) *Tables showing the results of the running of the clocks attached to the Instruments by Comparison of the R.A. Circles with a Chronometer.*

(The latest observations only are given.)

F. Perry's Instrument (*Mirror*).

d	Chronometer. h m s	R.A. Circle. h m
Dec. 20	3 35 38	23 52
	3 55 58	24 12
	4 8 10 5	24 24
Dec. 21	2 52 48	21 28
	3 1 26	21 32
	3 5 21	21 36
	3 9 14	21 40
Dec. 21	3 31 1	21 28
	4 7 6	22 4

Mr. Rooney's Instrument (*Lens*).

d	Chronometer. h m s	R.A. Circle. h m
Dec. 22	5 28 8	4 35
	5 33 12	4 30
	5 38 23	4 25
	5 43 26	4 20
	5 48 18	4 15
	5 53 6	4 10
	5 57 46	4 5
Dec. 22	6 37 49	4 25
	6 42 46	4 20
	6 47 57	4 15

Observer: Lieutenant J. F. Mills.

(δ) *Orientation of Plates, &c.*

Father Perry's Diary.—December 16.—[In absence of cardboard] Zinc cover made for mirror, with pinhole at centre:

5.30 tested perpendicularity of plate-holder to axis of tube with Sun; nearly correct; Sun too low before finishing. Tried at night with lamp, but could only confirm roughly.

December 17.—A very slight bending of the rods fastening the plate-holder made the reflected image of pinhole exactly coincident with direct image of Sun.

December 20.—Tried to get pinhole photographs, but clouds. Starlight night; mirror focussed by eye on ground glass and by photographs; the screws of the mirror are slightly short, so there is some danger in clamping at focus, only half the nut outside being available.

December 21.—Pinhole exposure at 7.49, but almost certainty of fogging.

New Zn plate for pinhole exposure, 1-inch aperture in same plate for 22nd.

Pinhole exposure poor.

[See also Mr. Rooney's Report.]

Lieutenant J. F. Mills' Report.—On the 23rd we tried to get pinholes with the lens and mirror at the same time as the eclipse had taken place the day before, but the Sun was not visible, and although it appeared a few minutes later for a few seconds, it was not bright enough to be of any use.

On the 24th it was just the same; in fact the day of the eclipse was the only day we had a bright Sun between 7.30 and 8.0 A.M. two or three days before, and after the eclipse, the Sun being behind the clouds at that time of the morning.

(ε) *Temperature during Eclipse.*

h	m		°	h	m		°
7	40		78½ F.	7	52	(Totality ends)	77
	45		78		53		78
	49		77½		55		77½
	50	(Totality begins)	77	8	0		78
	51		77				

Observer: Lieutenant J. F. Mills.

(ζ) *Weather, &c., during Totality.*

"At 7.20 A.M. on December 22 there was a very heavy fall of rain, the sky being overcast and gloomy, and it only cleared a few minutes before the eclipse, but we were fortunate in having it clear at the time of the eclipse."—*Lieutenant J. F. Mills.*

(η) *Eye observations of Corona.*

Captain G. L. Atkinson, of H.M.S. "Comus," notes during totality:—"Very few streamers; no disturbance; rose-hued Corona; prominences exceedingly bright and conspicuous."

After eclipse: "The general appearance of the Corona was a circle of yellow and rose-tinted light, with streamers towards the equator, and through a telescope the Corona was like the eclipse seen in America this year. None of the streamers reached beyond one diameter of the Sun. The prominences were very bright and conspicuous. There was very little disturbance, and the Corona prevented an almost unvarying appearance during the whole of totality. The Corona was very uniform in construction, even at the poles, but at the equator the streamers were a little more prolonged. A squall of rain just before the eclipse cleared the air, and luckily passed over in time, giving us a grand chance of observing it. The appearance of surrounding objects during totality was as if one saw them through a neutral tinted glass. . . . I observed a rift in the Corona about 30° to the proper left of the Sun's zenith. . . . The light during totality was greater than upon a bright moonlight night, and the temperature was slightly affected. . . . During three days before and after the eclipse the Sun was not visible at the hour the eclipse took place."

Lieutenant H. W. Thierens.—"I have the honour to report with regard to the total eclipse of the Sun observed by me through a telescope, that I noticed nothing different from the

report of the eclipse observed by the Americans this year, except I noticed during totality a red shadow which seemed to pass from the right-hand upper corner round the bottom, and seemed to disperse at the left-hand corner."

Lieutenant J. Beville Pym.—"Shortly after 7 A.M. on Sunday morning, December 22, 1889, Sergeant George Lidbury, R.M.L.I., and myself were in our places at the tower on the top of the military hospital, Salut. The sky was cloudy in all directions, but especially to eastward, and we could see nothing of the Sun until 7.30 A.M. The clouds then lifted, and passed gradually over our heads to westward. Shortly before 7.45 a heavy rain-squall passed us on the north side, going westward. This, together with the thick clouds, completely hid the view to westward until some time after the eclipse was over. At $7^h\ 28^m\ 5^s$ I observed a rainbow (bearing roughly W.S.W.) indistinctly through the clouds, and afterwards brighter.

"At $7^h\ 48^m\ 5^s$ I observed the reflection of these clouds in the sea getting very black. I took the time of this, as I thought it must be owing to the approach of shadow before totality. I could not at this time see anything to westward but these thick clouds and the rain-squall.

"At $7^h\ 50^m\ 8^s$ the whole face of the Earth became dark, and looking up at the Sun I saw that totality had commenced. [Drawing made during totality.]

"As soon as totality was over, and the light increased, I saw the shadow roll away and disappear to eastward at $7^h\ 52^m\ 35^s$, the sky being much clearer in that direction. I could see no shadows on the ground near me except those cast by natural objects before and after totality.

"Sergeant Lidbury says that just before totality the atmosphere appeared to him to be disturbed, and during totality he observed two spots on the limb of the Moon, the positions of which would correspond to the figures 4 and 8 in a clock. He also saw several colours round the Corona during totality."

Lieutenant A. H. Fanshawe.—"During totality observed long streamers, swallow-tailed at the ends, the sides being parallel and fairly hard lines; the horizontal lines of light being about half the diameter in extent, and $2\frac{1}{2}$ diameters in the long streamers. The long streamers were about 15° out of the vertical, the upper one to right, and lower to left. Also observed a bright star upon the right-hand upper quarter."

Mr. A. G. Yates.—"Before totality, when the Sun was about two-thirds obscured, I saw a few flashes of light straight to A (or even further), just like forked lightning."

[A is a point in the drawing five diameters from the limb, in the direction of the north point.]

E. *Cypher Codes.*

The code prepared for telegraphing general results was as follows:—

(Weather.)

The No.	1	represents	Weather good.
,,	2	,,	Weather moderate: clouds.
			(Lens Results.)
,,	3	,,	Completely successful, both exposure and development.
,,	4	,,	Exposure successful, development not.
,,	5	,,	Exposure partly successful, development good.
,,	7	,,	Exposure partly successful, development bad.
,,		,,	No results.
			(Mirror Results.)
,,	11	,,	Five alternatives just as for the lens.
,,	13	,,	
,,	16	,,	
,,	17	,,	
,,	19	,,	

Rule:—Select a number from each of the three divisions; multiply the three together and telegraph the result. The number 104 actually received splits up into the factors $2 \times 4 \times 13$.

A second cypher was arranged for telegraphing the general shape of the Corona, but was not used; it was as follows:—

Designate the directions E., W., N., S. by the prime numbers 2, 3, 5, 7 (more if necessary). Raise each prime to the power of the number of semi-diameters from the limb to which the Corona extends in the corresponding direction. Multiply the results together and telegraph the product.

Observations of the Moon made at the Radcliffe Observatory, Oxford, during the year 1889; and a Comparison of the Results with the Tabular Places from Hansen's Lunar Tables. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

The present paper contains the observations of the right ascensions and north polar distances of the Moon, made at the Radcliffe Observatory during the year 1889. These results are here compared with those deduced from Hansen's Lunar Tables on two suppositions :—

(1) That the mean times, found in the usual way from the sidereal times at mean noon, given in the *Nautical Almanac*, were *not* changed in 1864 by the adoption of a different unit of time.

(2) That these mean times *were* changed in 1864 by the adoption of a different unit of time to fix the positions of the clock stars relatively to the Sun, in accordance with the views which I have explained in papers communicated to the Society.

It will be seen that the mean annual error of Hansen's Tables from 1847 to 1863 is $-1''\cdot30$, and that no law of regular increase is apparent; but that, with the argument in the Tables taken out in the usual way, the mean annual error has since increased at an average rate of $0''\cdot72$ per annum, the error now amounting to more than $+17''$. The mean annual error of Hansen's Tables from 1864 to 1889 taken out with the *corrected* argument is $-1''\cdot36$, which is almost identically the same as the mean error between 1847 and 1863.

For facilities for an accurate comparison between Hansen's Lunar Tables and observations I am again indebted to the places published in the *Connaissance des Temps*.

TABLE I.

Radcliffe Observations of the Moon, 1889.

R.A.'s and N.P.D.'s of the Centre of the Moon, compared with Hansen's Tabular Places, **Uncorrected** *and* **Corrected** *for the Change in the Unit of Mean Time introduced in the year* 1864.

Day, 1889.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s		h m s	s	s	s	s	° ′ ″	″	″	″	″
Jan. 12	37·15	F. B.	4 14 49·75	50·81	+1·06	−1·24	−0·18	72 38 32 39	29·21	−3·18	+4·37	+1·19
17	37·17	F. B.	8 40 36·35	37·74	+1·39	−1·35	+0·04	70 8 7·10	9·88	+2·78	−3·30	−0·52
21	37·18	F. B.	12 10 50·80	51·86	+1·06	−1·29	−0·23	85 46 47·87	53·49	+5·62	−7·65	−2·03
22	37·19	W.	13 2 30·51	31·63	+1·12	−1·30	−0·18	90 59 3·73	11·77	+8·04	−7·90	+0·14
Feb. 7	37·25	W.	3 6 57·58	58·62	+1·04	−1·20	−0·16	77 19 17·93	11·70	−6·23	+5·80	−0·43
8	37·26	R.	3 55 22·32	23·22	+0·90	−1·23	−0·33	73 46 57·63	52·34	−5·29	+4·83	−0·46
9	37·26	F. B.	4 45 12·04	13·12	+1·08	−1·27	−0·19	70 57 28·47	25·41	−3·06	+3·64	+0·58
11	37·27	W.	6 29 50·34	51·24	+0·90	−1·35	−0·45	67 59 51·32	51·61	+0·29	+0·69	+0·98
12	37·27	R.	7 24 9·91	10·76	+0·85	−1·37	−0·52	68 5 50·04	50·16	+0·12	−0·99	−0·87
14	37·28	W.	9 13 46·91	48·04	+1·13	−1·36	−0·23	71 41 43·57	46·74	+3·17	−4·33	−1·16
15	37·28	W.	10 7 52·01	53·09	+1·08	−1·34	−0·26	75 4 38·49	42·63	+4·14	−5·77	−1·63
16	37·29	W.	11 1 6·04	7·28	+1·24	−1·32	−0·08	79 18 51·35	55·36	+4·01	−6·90	−2·89
21	37·31	R.	15 29 48·44	49·66	+1·22	−1·44	−0·22	104 32 5·30	9·78	+4·48	−6·37	−1·89

Day, 1889	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s		h m s	s	s	s	s	° ′ ″	″	″	″	″
Feb. 22	37·31	R.	16 28 52·32	53·53	+ 1·21	− 1·51	−0·30	108 18 13·51	17·96	+ 4·45	− 4·85	−0·40
Mar. 11	37·38	W.	7 0 52·39	53·42	+ 1·03	− 1·35	−0·32	67 45 6·50	6·76	+0·26	−0·30	−0·04
13	37·39	R.	8 49 43·60	44·62	+ 1·02	− 1·37	−0·35	70 24 54·50	56·35	+ 1·85	− 3·69	− 1·84
15	37·40	W.	10 37 56·20	57·23	+ 1·03	− 1·35	−0·32	77 20 56·39	61·89	+ 5·50	− 6·60	− 1·10
16	37·40	R.	11 31 24·38	25·43	+ 1·05	− 1·34	−0·29	82 5 9·57	14·50	+ 4·93	− 7·61	− 2·68
21	37·42	F. B.	16 10 19·08	20·61	+ 1·53	− 1·51	+0·02	107 28 39·86	45·27	+ 5·41	− 5·48	−0·07
22	37·42	R.	17 11 50·30	51·65	+ 1·35	− 1·56	−0·21	110 30 15·75	17·37	+ 1·62	− 3·53	− 1·91
Apr. 15	37·52	R.	13 48 29·42	30·41	+ 0·99	− 1·42	−0·43	95 56 2·21	8·80	+ 6·59	− 8·47	− 1·88
May 6	37·60	R.	8 5 4·96	5·62	+ 0·66	− 1·34	−0·68	68 16 54·71	54·45	−0·26	− 2·29	− 2·55
16	37·64	F. B.	17 24 26·51	28·12	+ 1·61	− 1·67	−0·06	111 19 44·54	49·17	+ 4·63	− 3·42	+ 1·21
21	37·66	R.	22 36 56·08	57·47	+ 1·39	− 1·35	+0·04	103 11 55·80	47·82	− 7·98	+ 6·73	− 1·25
June 5	37·72	R.	10 22 42·44	42·96	+ 0·52	− 1·29	−0·77	75 33 29·51	31·82	+ 2·31	− 6·05	− 3·74
13	37·76	F. B.	17 57 19·22	20·85	+ 1·63	− 1·72	−0·09	112 17 12·39	13·87	+ 1·48	− 2·26	− 0·78
18	37·78	R.	23 10 57·44	58·78	+ 1·34	− 1·34	0·00	100 21 11·08	3·85	− 7·23	+ 7·41	+ 0·18
July 5	37·84	R.	12 35 55·62	56·22	+ 0·60	− 1·28	−0·68	88 7 52·34	58·35	+ 6·01	− 8·06	− 2·05
6	37·85	F. B.	13 26 50·53	51·50	+ 0·97	− 1·32	−0·35	93 29 25·97	31·06	+ 5·09	− 8·25	− 3·16
10	37·86	R.	17 22 3·20	4·44	+ 1·24	− 1·68	−0·44	111 15 50·77	53·54	+ 2·77	− 3·60	− 0·83
16	37·89	R.	23 41 4·26	5·54	+ 1·28	− 1·33	−0·05	97 28 50·38	43·28	− 7·10	+ 7·91	+ 0·81

Day, 1889.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s		h m s	s	s	s	s	° ′ ″	″	″	″	″
July 18	37·90	R.	1 21 3·63	4·92	+1·29	−1·23	+0·06	87 5 46·20	37·96	−8·24	+7·74	−0·50
Aug. 5	37·97	F. B.	15 52 26·00	27·21	+1·21	−1·50	−0·29	106 37 36·03	41·07	+5·04	−6·20	−1·16
6	37·97	R.	16 53 29·67	30·61	+0·94	−1·60	−0·66	110 9 12·32	16·46	+4·13	−4·44	−0·31
7	37·98	F. B.	17 58 10·52	11·69	+1·17	−1·67	−0·50	112 20 52·76	55·18	+2·42	−2·14	+0·28
Sept. 6	38·10	R.	20 48 14·33	15·46	+1·13	−1·60	−0·47	110 23 47·30	42·89	−4·41	+4·38	−0·03
7	38·10	F. B.	21 49 41·74	42·95	+1·21	−1·52	−0·31	106 52 33·47	30·48	−2·99	+6·27	+3·28
9	38·11	W.	23 42 49·89	51·25	+1·36	−1·37	−0·01	97 7 57·95	50·01	−7·94	+8·26	+0·32
10	38·11	W.	0 35 13·52	14·87	+1·35	−1·32	+0·03	91 40 54·84	48·11	−6·73	+8·40	+1·67
12	38·12	F. B.	2 15 38·02	39·39	+1·37	−1·27	+0·10	81 13 36·42	30·55	−5·87	+7·44	+1·57
15	38·13	R.	4 46 29·19	30·20	+1·01	−1·32	−0·31	69 52 49·14	46·88	−2·26	+3·88	+1·62
16	38·14	F. B.	5 38 32·89	34·08	+1·19	−1·35	−0·16	67 51 35·74	35·88	+0·14	+2·32	+2·46
17	38·14	W.	6 31 28·49	29·62	+1·13	−1·36	−0·23	66 53 45·13	44·15	−0·98	+0·64	−0·34
Oct. 3	38·20	W.	20 26 35·69	36·96	+1·27	−1·59	−0·32	111 29 55·63	51·83	−3·80	+3·61	−0·19
4	38·21	R.	21 27 27·02	28·32	+1·30	−1·52	−0·22	108 28 40·62	34·94	−5·68	+5·57	−0·11
5	38·21	F. B.	22 25 17·54	19·03	+1·49	−1·44	+0·05	104 19 63·39	59·59	−3·80	+7·05	+3·25
7	38·22	F. B.	0 12 36·43	37·68	+1·25	−1·32	−0·07	94 3 63·22	57·90	−5·32	+8·41	+3·09
8	38·22	W.	1 3 22·52	23·77	+1·25	−1·29	−0·04	88 36 38·41	31·61	−6·80	+8·35	+1·55
9	38·23	R.	1 53 17·76	18·93	+1·17	−1·28	−0·11	83 19 39·57	32·61	−6·96	+7·88	+0·92

Day, 1889.	Correction to be subtracted from M.T. for change of Sidereal Time at Mean Noon since 1864.	Observer.	Observed R.A.	R.A. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**	Observed N.P.D.	N.P.D. from Hansen's Tables for Uncorrected Mean Times.	Hansen *minus* Observed. **Uncorrected.**	Correction due to the Change in the Unit of Mean Time.	Hansen *minus* Observed. **Corrected.**
	s		h m s	s	s	s	s	° ′ ″	″	″	″	″
Oct. 13	38·24	R.	5 16 43·07	44·07	+ 1·00	− 1·35	− 0·35	68 19 19·23	18·08	− 1·15	+ 3·03	+ 1·88
31	38·32	W.	21 9 46·52	47·80	+ 1·28	− 1·54	− 0·26	109 44 39·59	35·15	− 4·44	+ 5·05	+ 0·61
Nov. 1	38·32	R.	22 7 53·65	54·94	+ 1·29	− 1·45	− 0·16	105 55 28·66	23·28	− 5·38	+ 6·63	+ 1·25
2	38·32	F. B.	23 2 38·88	40·25	+ 1·37	− 1·37	0·00	101 15 47·05	42·72	− 4·33	+ 7·67	+ 3·34
4	38·33	W.	0 44 49·44	50·54	+ 1·10	− 1·28	− 0·18	90 42 9·39	3·17	− 6·22	+ 8·37	+ 2·15
8	38·35	R.	4 3 34·69	35·87	+ 1·18	− 1·32	− 0·14	71 58 30·79	24·24	− 6·55	+ 5·25	− 1·30
12	38·36	W.	7 35 7·77	9·04	+ 1·27	− 1·37	− 0·10	66 42 57·57	57·25	− 0·32	− 1·42	− 1·74
27	38·42	R.	20 49 35·38	36·51	+ 1·13	− 1·61	− 0·48	110 57 30·34	25·37	− 4·97	+ 4·52	− 0·45
28	38·43	F. B.	21 50 13·94	15·51	+ 1·57	− 1·50	+ 0·07	107 24 29·02	23·91	− 5·11	+ 6·32	+ 1·21
Dec. 2	38·44	W.	1 18 34·29	35·33	+ 1·04	− 1·25	− 0·21	87 8 48·78	42·72	− 6·06	+ 8·19	+ 2·13
3	38·45	R.	2 6 52·64	53·67	+ 1·03	− 1·25	− 0·22	82 1 40·45	34·59	− 5·86	+ 7·67	+ 1·81
10	38·49	W.	8 8 42·74	43·97	+ 1·23	− 1·36	− 0·13	67 25 3·58	5·85	+ 2·27	− 2·48	− 0·21
31	38·56	R.	2 40 22·55	23·44	+ 0·89	− 1·26	− 0·37	78 46 8·15	1·01	− 7·14	+ 7·15	+ 0·01
Mean of Errors, without regard to sign		...	...	s 1·161	...	s 0·243	...	...	...	4″·342	...	1″·322
Mean Errors for Year		...	...	...	+1·161	...	−0·230					

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; F. B., Mr. F. A. Bellamy.

TABLE II.

Radcliffe Observations of the Moon, 1889.

Errors of the Moon's Tabular Place in Longitude and Ecliptic Polar Distance, **Uncorrected** *and* **Corrected** *for the Change in the Unit of Mean Time introduced in the year* 1864.

Day, 1889.		Errors of Longitude (Hansen *minus* Observed).		Errors of E.N.P.D. (Hansen *minus* Observed).	
		Uncorrected.	**Corrected.**	**Uncorrected.**	**Corrected.**
		″	″	″	″
Jan.	12	+15·53	− 2·75	−0·44	+0·71
	17	+19·68	+ 0·41	−2·34	−0·65
	21	+16·90	− 3·99	−1·17	−0·49
	22	+18·64	− 2·44	+0·95	+1·17
Feb.	7	+16·41	− 2·14	−1·80	−1·06
	8	+13·81	− 4·57	−2·51	−1·43
	9	+15·61	− 2·75	−1·10	+0·23
	11	+12·52	− 6·20	−0·37	+1·31
	12	+11·71	− 7·28	−1·58	+0·18
	14	+16·31	− 3·47	−1·77	−0·13
	15	+16·13	− 4·11	−1·63	−1·20
	16	+18·47	− 2·21	−3·37	−2·21
	21	+18·33	− 3·57	+0·04	−1·06
	22	+17·74	− 4·29	+1·72	+0·27
March	11	+14·24	− 4·28	−1·21	+0·40
	13	+14·39	− 5·26	−2·10	−0·44
	15	+16·09	− 4·77	−0·55	+0·73
	16	+16·32	− 5·03	−1·66	−0·75
	21	+22·56	+ 0·27	+1·29	−0·12
	22	+19·05	− 3·10	+0·04	−1·66
April	15	+16·21	− 6·69	+0·90	+0·53
May	6	+ 8·95	− 9·80	−2·16	−0·53
	16	+22·75	− 0·76	+3·22	+1·26
	21	+21·86	+ 1·01	+0·19	−0·94
June	5	+ 7·89	−11·81	−0·59	+0·57
	13	+22·61	− 1·25	+1·38	−0·77
	18	+21·10	− 0·07	+1·05	+0·17
July	5	+10·72	−10·26	+2·00	+2·13
	6	+15·45	− 6·07	−0·69	−0·98
	10	+17·47	− 6·19	+1·61	−0·42
	16	+20·38	− 1·01	+1·07	+0·45
	18	+21·10	+ 1·03	−0·39	−0·13

Day, 1889.		Errors of Longitude (Hansen *minus* Observed).		Errors of E.N.P.D. (Hansen *minus* Observed).	
		Uncorrected.	Corrected.	Uncorrected.	Corrected.
		″	″	″	″
Aug.	5	+18·12	−4·33	+1·25	−0·25
	6	+13·63	−9·27	+2·61	+0·74
	7	+16·23	−6·93	+2·36	+0·30
Sept.	6	+16·49	−6·36	−0·01	−1·79
	7	+17·38	−5·30	+3·03	+1·59
	9	+21·82	−0·26	+0·76	+0·23
	10	+21·41	−0·25	+1·78	+1·72
	12	+21·18	+0·88	+1·19	+1·97
	15	+14·41	−4·54	−0·43	+1·05
	16	+16·49	−2·31	+0·76	+2·37
	17	+15·51	−3·19	−1·85	−0·16
Oct.	3	+18·14	−4·30	+0·51	−1·24
	4	+19·38	−2·94	+0·42	−1·09
	5	+21·59	−0·52	+4·39	+3·29
	7	+19·42	−2·21	+2·58	+2·43
	8	+19·96	−1·15	+0·91	+1·20
	9	+18·83	−1·86	−0·38	+0·28
	13	+14·01	−5·01	−0·09	+1·50
	31	+18·61	−3·69	+1·09	−0·50
Nov.	1	+19·36	−2·61	+1·52	+0·36
	2	+20·34	−1·30	+3·79	+3·08
	4	+17·73	−3·35	+0·74	+0·92
	8	+17·82	−1·71	−3·18	−1·66
	12	+17·23	−1·64	−3·15	−1·49
	27	+16·60	−6·36	−0·53	−2·24
	28	+22·94	+0·54	+2·76	+1·48
Dec.	2	+16·77	−3·73	+0·27	+0·78
	3	+16·44	−3·70	−0·30	+0·59
	10	+17·15	−1·81	−1·37	+0·17
	31	+14·69	−5·19	−2·79	−1·65
Mean of Errors, without regard to sign		**...17″·365**	**3″·646**	**1″·447**	**1″·019**
Mean Errors for Year		**+17″·365**	**−3″·513**		

TABLE III.

Mean Excess over Observation of the Moon's Tabular Place in Longitude for the years 1847 *to* 1889, *as Computed from Hansen's Tables.*

Uncorrected *and* **Corrected** *on and after* 1864 *for the change in the Unit of Mean Time introduced in the year* 1864.

Year.	Errors of Longitude (Hansen *minus* Observed).	
	Uncorrected.	**Corrected.**
	″	″
1847*	+ 1·07	+ 1·07
1848	+ 0·20	+ 0·20
1849	− 0·47	− 0·47
1850	− 0·28	− 0·28
1851	− 1·29	− 1·29
1852	− 0·92	− 0·92
1853	− 1·63	− 1·63
1854	− 1·68	− 1·68
1855	− 0·87	− 0·87
1856	− 0·96	− 0·96
1857	− 1·86	− 1·86
1858	− 1·98	− 1·98
1859	− 1·80	− 1·80
1860	− 2·90	− 2·90
1861	− 2·19	− 2·19
1862	− 2·83	− 2·83
1863	− 1·61	− 1·61
1864	+ 0·12	− 0·81
1865	+ 1·27	− 0·22
1866	+ 2·14	− 0·22
1867	+ 3·48	+ 0·36
1868	+ 4·12	+ 0·28
1869	+ 4·28	− 0·35
1870	+ 4·83	− 0·66
1871	+ 6·96	+ 0·44
1872	+ 7·31	+ 0·10
1873	+ 8·24	+ 0·20
1874	+ 9·29	+ 0·56
1875	+ 9·87	+ 0·36
1876	+ 9·80	− 0·50
1877	+ 9·23	− 1·90
1878	+ 8·22	− 3·60
1879	+ 9·63	− 3·12
1880†	+ 10·89	− 2·77
1881	+ 10·51	− 4·06
1882	+ 12·68	− 2·51
1883‡	+ 14·71	− 1·50
1884	+ 14·65	− 1·91
1885	+ 15·20	− 1·82
1886	+ 15·34	− 2·53
1887	+ 15·70	− 3·25
1888	+ 17·68	− 2·46
1889	+ 17·37	− 3·51

Radcliffe Observatory, Oxford:
1890 *March* 11.

* 1847 to 1879, Greenwich observations.
† 1880 to 1882, Mean of Greenwich and Radcliffe.
‡ 1883 to 1889, Radcliffe observations.

A New Class of Binary Stars. By Professor Edward C. Pickering.

A study of the photographic spectra of the stars undertaken as a memorial to Dr. Henry Draper has been in progress for several years at the Harvard College Observatory. This has led to the detection of certain binary stars whose components are too close to be separated by ordinary means. Suppose the two components of such a binary to have similar dimensions and identical spectra, and to revolve around each other in a circular orbit whose plane passes near the Sun. When the stars are in conjunction both are moving perpendicular to the line of sight, their spectra will be superposed, and it will be impossible to distinguish them from a single star. After making a quarter of a revolution or at elongation, however, one star will be approaching the observer rapidly, and all the lines in its spectrum will accordingly be moved slightly towards the blue end of the spectrum. The other star will be receding and its lines will be carried towards the red end. The two spectra will thus be separated so that every line will appear double. After another quarter of a revolution the motion will again be perpendicular to the line of sight and the lines will be single. At the next elongation the lines will be again double, but reversed, so that the star which was before approaching is now receding.

The occasional doubling of the K line in the spectrum of *ζ Ursæ Majoris* has already been announced. A careful study was made of this star last autumn. In all 113 photographs have been obtained on 80 nights. These seem to show that the lines became double at intervals of 52 days, corresponding to a period of revolution of 104 days. It now seems probable that the period should be reduced one half. Owing to the low altitude of the star the first photographs were often poor, but now that it rises higher during the night the law regulating the phenomenon will soon be determined. The spectrum is that of the first type in which the principal lines are those due to hydrogen, and are too broad to permit a slight separation to be detected in them. The other lines, except the K line, are very faint, and when double are seen with difficulty. The best photographs, however, show that several of these also are double, the separation being proportional to the wave-length of the line. The maximum separation of the K line somewhat exceeds 0·2 millionth of a millimetre, corresponding to a relative velocity of one star compared with the other of about a hundred miles a second.

A similar case has been discovered by Miss A. C. Maury, who is making a careful study of the spectra of the brighter stars. The star *β Aurigæ*, from 47 photographs on 30 nights, shows a distinct doubling of its lines at intervals of almost exactly two days, indicating a period of revolution of four days. The lines

are therefore alternately single and double on successive nights. The first indication of the doubling of the lines is that they become hazy, and the change is so rapid that it can sometimes be detected in successive photographs or in the two edges of the same spectrum. The width of the photographed spectrum, as explained elsewhere, is due to the gradual progress of the actual spectrum over the plate, in consequence of an intentional difference between the rate of the clock and the diurnal motion.

The type of spectrum resembles that of *ζ Ursæ Majoris*, but the hydrogen lines are finer, and the faint lines are better shown. About one hundred and fifty lines in all are visible when single, and in some photographs about a dozen of the more marked lines can be seen to be double, the others becoming hazy or invisible. The maximum separation of the K line is about 0·3 units, or three millimetres on the scale of the map of Ångström. The corresponding velocity is about one hundred and fifty miles per second. Hence it may be inferred that the distance of the two stars is about eight millions of miles, and that their total mass is 2·3 times that of the Sun. In other words, if two stars, each having a mass about one-fifth greater than that of the Sun, were placed eight millions of miles apart, and were made to revolve in a circular orbit, the observed phenomenon would be produced. The velocity here given is that of the component of the motion parallel to the line of sight. If the plane of the orbit does not pass through the Sun, the total velocity, radius, and masses will be proportionately increased.

The analytical conditions for determining the exact form of the orbit are comparatively simple. In the formulæ for elliptic motion it is only necessary to place the differential coefficient of the component of the motion parallel to the line of sight equal to the separation, and discuss its variation with the time. The results are reduced to absolute distances by the usual formula. (See *Proc. Amer. Acad.* xvi. 8.) If the orbit is circular the curve is that of sines. If elliptic, with the major axis directed towards the Sun, the maximum separation of the lines will not occur midway between the times at which the lines are single. If the major axis is perpendicular to the line of sight, the alternate separations will vary in amount, and the time required for any line to become single will be alternately long and short. This last case seems to be represented by *ζ Ursæ Majoris*, while the orbit of *β Aurigæ* seems to be nearly circular.

In *β Aurigæ* the more refrangible of the two components of the K line appears to be generally the more intense of the two, instead of becoming alternately brighter and fainter as might be expected if due to a real difference in the spectra of the two components. This is perhaps due to additional faint lines of somewhat shorter wave-length than K.

No satisfactory measurement has as yet been made of the parallax of *β Aurigæ*. We may, however, compare it with *α Aurigæ*, whose parallax, according to Dr. Elkin, is 0″·11. The

proper motion of *α Aurigæ*, according to Auwers, is 0″·43, of *β Aurigæ* 0″·07. The ratio of the light is as 5·7 to 1. Accordingly, if *α Aurigæ* was removed to 6 times its present distance its proper motion would be about that of *β Aurigæ*; while if its distance was increased 2·4 times the brightness of he two stars would be about the same. This last quantity should probably be further increased owing to the greater intrinsic brightness of *β Aurigæ*. Estimates of distance based on these facts are of course uncertain, but they do not encourage us to anticipate a greater parallax for *β Aurigæ* than 0″·05. The maximum separation of the components would then be 0″·004. The maximum separation of the lines in the spectrum is about 20″. Accordingly in this case the spectroscope may be said to make the apparent angle of separation about 5,000 times as great as it would be without the aid of the prism. If a binary star was found, one of whose components appeared to describe in four days an orbit of the size of the disc of *Jupiter*, we should regard it as a remarkable object. Yet this is the scale of the apparent motion of the components of the lines of the spectrum.

No binary star has hitherto been discovered having a period less than several years. The presence of dark bodies revolving in a few days around variable stars of the Algol type, however, indicates a phenomenon resembling that here described.

In view of the great velocity of these stars it might be thought that even a rare resisting medium would be sufficient to convert their energy rapidly into heat. Probably, however, such a medium would revolve with the stars, and its effect would therefore be small. There is no evidence of a change in brightness of *β Aurigæ* during the last two thousand years, as is shown by the following determinations of its light (*H. C. Annals*, xiv. 145): Ptolemy, A.D. 138, mag. 2·1; Sûfi, A.D. 964, mag. 2·0; W. Herschel, 1795, mag. 1·9; J. Herschel, 1835, 2·3; Harvard Photometry, 1880, mag. 2·1. The corresponding magnitudes for *ζ Ursæ Majoris* are 2·1, 2·0, 2·2, 2·2, and 2·4.

It is needless to add that the investigation is still in progress. Additional photographs are being taken, and a complete discussion will appear later. Similar changes are also suspected in several other stars. Photographs are accordingly taken of them at short intervals.

Harvard College Observatory:
Cambridge U.S. 1890 *January* 8.

γ Coronæ Australis. By E. B. Powell.

The orbit for *γ Coronæ Australis* now submitted has been derived by the graphical method laid down by Sir John Herschel. The accordance between observation and calculation seems pretty fair, except in the case of the later distances; these imply that the distance is increasing, but there appears no doubt of its being on the decrease. By calculating the sectorial areas, the annual sector afforded by past observations does not differ much from ·087 of a square second; but the Windsor (Australia) measures give an area much in excess, indicating that the distances for 1887 and 1888 are very considerably greater than they should be. At the same time, as the agreement between observation and calculation is mainly for the north preceding side of the perspective ellipse, it is possible the apparent orbit does not possess *quite* sufficient width, but turns the southern end *somewhat* prematurely. If this be so, the projected centre of the orbit will be thrown more on the following side, and the position of the periastron will require to be a little advanced. Also, as the method pursued in arriving at the orbit draws some of the elements from a, the position-angle of the periastron, it may be found necessary to modify the dependent elements to a slight extent.

The period and the time of periastron passage were obtained from six equations of mean motion: the separate results were very fairly harmonious, the mean value of P not differing from the extremes by more than about half a year, and the mean value of T differing still less from its extremes.

The orbit agrees fairly well with the measures of Herschel, Jacob (excepting for the epoch 1850·46), and Schiaparelli. The greatest angular discrepancy, +2°·1, attaches to my own measure for 1870·1, which, as mentioned in my paper published in the *Monthly Notices*, No. 1, for November 1883, was the result of observations taken with an eyepiece of low power, my usual eyepiece having been lost. It seems there is greater difficulty generally in measuring the distance than in taking the angle of position of the star. This I experienced with my 5-foot equatoreal carrying a 4-inch object-glass. The smallness and the equality of the components enable an observer to lay a spider-line pretty accurately across their centres; but, without a tolerably high power, it is far from easy to measure the distance satisfactorily. In my own case the distance was beyond my telescope, and I never did more than make an estimate of it. If I might be allowed, I would suggest that two or three observers possessing powerful telescopes should give attention just now to this binary. The comes is running in to its smaller minimum distance, 1″ or a little more, and careful measures would enable a really excellent orbit to be deduced after the lapse of a few years.

Elements.

$a = 211°$ $\lambda = 153° 21' 19''$
$\Omega = 49° 17' 30''$
$\gamma = 48° 47' 23''$
$e = \cdot 302872$
P = 93·338 years, mean annual motion = 3° 51′ 25″ retrograde.
T = 1885·192
$a = 2''\cdot 034$

It would be premature at present to find variations of the position-angles for variations of the elements, and deduce corrections for the latter by means of the method of least squares; I have therefore made no attempt in this direction.

Appended is a comparison of observed and calculated results, in which most of the measures taken are introduced.

Comparison of Observed and Calculated Results.

Observer.	Epoch 1800+.	θ_o	d_o	θ_c	d_c	$\theta_o - \theta_c$	$d_o - d_c$
		°	′	°	″	°	″
Herschel	34·47	37·1	...	37·3	2·56	− ·2	...
,,	35·55	36·8	...	35·7	...	+1·1	...
,,	36 43	34·5	...	34 3	...	+ 2	...
,,	37·43	32·7	2·66	32·7	2·52	0	+·14*
Jacob	47·32	14·1	2·30	15·0	2·17	− ·9	+·13
,,	50 46	5·9	2 29	7·8	2 02	−1·9	+·27
,,	51·54	4·5	2·26	5·1	1·96	− ·6	+·30
,,	52·49	2·2	1·9	2·6	1·91	− ·4	−·01
,,	53·52	359·0	1 83	359 7	1·86	− ·7	−·03
,,	54·26	356·2	1·71	357·5	1·82	−1·3	−·11
,,	56·44	349·4	1·67	350·5	1 71	−1·1	−·04
,,	57·44	347·4	1·61	346·9	1·66	+ ·5	−·05
,,	58·20	343·4	1·53	344·1	1·62	− ·7	−·09
Powell	59·72	338·1	1½ est.	338·0	1·55	+ ·1	...
,,	61 69	328·8	...	329·4	...	− ·6	...
,,	62·27	325·3	1½ est.	326·7	1·45	−1·4	...
,,	63·84	318·1	...	319 0	...	− ·9	...
,,	70·19	286·9	...	284·8	...	+2·1	...
Schiaparelli	75·65	257·4	1·45	257·0	1·45	+ ·4	0
Howe	76·65	253·1	1 67	252·2	1·46	+ ·9	+·21
Schiaparelli	77·43	248·4	1·49	248·6	1·47	− ·2	+·02
Howe	78·49	242·9	1·47	243·7	1·48	− ·8	−·01
Burnham	79·69	240·0	·87	238·2	1·47	+1·8	−·60
Hargrave	80·67	232·4	1·32	233·7	1·47	−1·3	−·15
Wilson	83·62	217·7	1 62	219·4	1·40	−1·7	+·22
Pollock	86·615	200·6	1·45	202·6	1·27	−2·0	+·18
Tebbutt	87·728	196·2	1·68	195·3	1·21	+ ·9	+·47
,,	88·67	188·7	1·77	188·6	1·16	+ ·1	+·61

* d_o for 37·21 years.

The following particulars afforded by the orbit may be noted. The greater maximum distance was 2″·58 nearly, for position equal to 41°, and for epoch 1832: the annual angular motion was then about 1°·5. The smaller maximum distance was 1″·48, for position equal to 244° nearly, and epoch about 1878·5. The greater minimum distance was 1″·33 approximately, for position equal to 297°, and epoch about 1868. The smaller minimum distance will be 1″·05 nearly, for position equal to 154°, and epoch about 1892·8: the annual angular motion will then be nearly 9°. Thus the greatest annual angular motion will be about six times the least.

Streatham Hill.

A Simple Method of obtaining an Approximate Solution of Kepler's Equation. By Arthur A. Rambaut, M.A.

(*Communicated by Sir R. S. Ball, LL.D., F.R.S.*)

From time to time a good many suggestions have been made for obtaining approximate solutions of the equation

$$u - e \sin u = nt;$$

but, although some of these are very useful when required in the case of one particular orbit, I know of no method, at once so simple and so easily applied to a number of orbits, as the following, which occurred to me when calculating the true anomalies for the binaries, given in Table II. of the following communication.

It depends on the principle that the abscissa of a prolate trochoid, generated by the rolling of a circle along a line parallel to the axis of x, is given by the equation

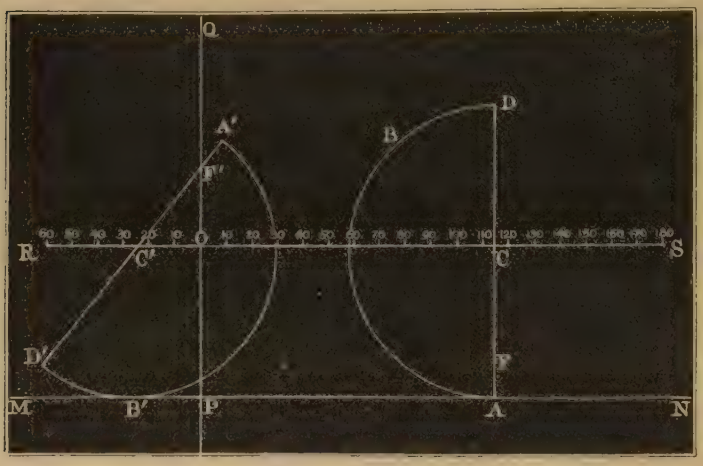
$$x = a\theta - d \sin \theta.$$

The construction will at once be seen from a description of the apparatus I made for myself, and by the aid of which I was able to obtain u for any orbit, to a quarter of a degree or so in about half a minute.

This degree of precision was, of course, quite sufficient for my purpose, but in various researches connected with double stars, such, for instance, as the comparison of the elements with the data or the construction of an ephemeris, a solution of this kind would, I think, furnish a very good first approximation.

In the figure, MN represents the edge of a straight ruler, glued to a sheet of millimetre paper, about 500^{mm} long and 250^{mm} broad, and which coincides with one of the lines on the paper. PQ is a line drawn at right angles to the ruler, at a distance of about 130^{mm} from the left edge of the paper. At a distance of 102^{mm} from the ruler is a line ROS parallel to it, and graduated to the right and left of PQ in degrees, on the scale of 314^{mm}·159 to 180°. ABD and A′B′D′ represent two

positions of a piece of stout cardboard, carefully cut in the form of a semicircle of 200mm diameter, the radius CA being



Kepler's Equation.

graduated in millimetres. A point F is taken on CA, so that $\frac{CF}{CA} = e$.

To use the apparatus, all that is necessary is to set AD at right angles to RS (which is easily done by the lines on the paper) at a distance from PQ equal to the mean anomaly (nt), and to roll the semicircular card along the ruler until the point F lies on the line PQ. Then the distance OC′ is equal to $u - nt$.

It only remains, therefore, to add OC′, which is obtained in degrees directly from the scale RS, to nt in order to obtain u in degrees.

In the example illustrated in the figure, I have taken nt equal to twice the angular unit $= 114°{\cdot}6$ and $e = 0{\cdot}75$. By rolling the card I find

$$OC' = 26°{\cdot}8 ;$$

whence

$$u = 114°{\cdot}6 + 26°{\cdot}8 = 141°{\cdot}4.$$

On the Parallax of Double Stars. By Arthur A. Rambaut, M.A.

(*Communicated by Sir R. S. Ball, LL.D., F.R.S.*)

In a paper published in the *Proceedings of the Royal Irish Academy* (2nd ser., vol. iv., No. 6), I pointed out the relation connecting the parallax and the relative velocity of the compo-

nents of a double star with the period and angular elements of its orbit, and discussed the possibility of determining the distance by means of spectroscopic observations of this velocity.

At the time my paper was read (May 1886), my examination of the question seemed to point to the conclusion that the velocities to be expected were too small to be measured with any degree of certainty, and although the photographic method even then wore a very promising appearance, it seemed that, for some time to come, at least, there was but little prospect of success in this direction.

Since that date, however, the splendid progress made by Professor Pickering and others in the art of photographing stellar spectra has altered the whole aspect of the question, and in particular the magnificent series of results, lately published in the *Astronomische Nachrichten* by Professor Vogel and Dr. Scheiner, seems to demonstrate the possibility of applying this method with success to the determination of parallax.

It is in the hope of inducing astronomers who may be engaged on this kind of observation, or who have the requisite instruments at their disposal, to take up what, under present circumstances, appears to me a promising field of work that I venture once more to direct attention to the subject.

In my paper before referred to (p. 666) I have shown that if

ϕ denotes the angle between the tangent to the orbit and the major axis,
λ " " angle between the line of nodes and the major axis,
γ " " inclination
a " " semi-axis-major
e " " eccentricity
r " " radius vector
} of the orbit,
P " " period,
π " " parallax in secs. of arc
V " " velocity in miles per sec. in the line of sight
} of the star,
l " " mean motion of the Earth in miles per second,

then

$$\pi V = \frac{la^2\sqrt{1-e^2}\,\sin(\phi-\lambda)\sin\gamma}{Pr\sqrt{1-e^2\cos^2\phi}}.$$

This equation gives us a relation between π and V depending only on the period and angular elements of the orbit, by means of which, if V has been determined by observation, π can be immediately deduced.

In my previous paper I took unity as the critical value of πV for this reason, that if πV is at any time equal to unity, we know either that π is not less than one-tenth of a second of arc, or that V is not less than ten miles per second—ten miles appearing to me at that time as being about the limit of velocity which could with certainty be detected.

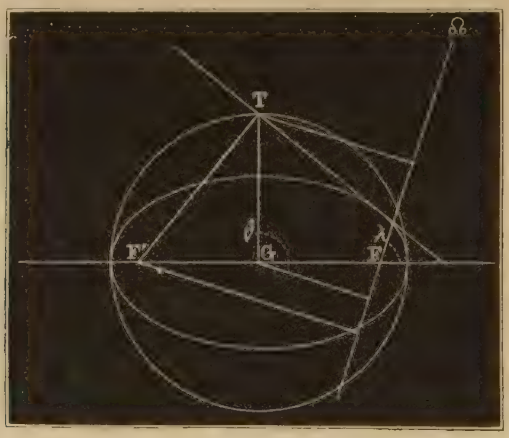
A perusal of Professor Vogel's paper in Nos. 2896 and 2897 of the *Astronomische Nachrichten* shows, however, that this value may now be very much reduced. He there gives, amongst other results, ten different values for the motion of α *Aurigæ* in the line of sight, obtained on different nights, all lying between $+3{\cdot}1$ and $+4{\cdot}0$ German geographical miles, while his results for *Venus* agree within a tenth of a geographical mile with the calculated values. If, then, we assume that, where the components are fairly equal in brightness, a velocity of one English mile per second is not quite beyond the capabilities of the spectrographic method, we shall find that a number of double stars whose orbits have been determined are within measurable distance either by the trigonometrical or spectrographic method, so far, at least, as the values of π and V are concerned.

This being the case it seems to me desirable to reduce the formulæ to a more convenient shape, and to compute πV for some other stars not included in my previous paper.

I have shown (p. 667) that we may write

$$\pi \mathrm{V} = \frac{lap' \sin(\phi - \lambda) \sin \gamma}{\mathrm{P}b},$$

where b is the semi-axis-minor and p' the perpendicular from the



Parallax of Double Stars.

empty focus on the tangent to the orbit. Also $p' \sin(\phi - \lambda)$ is the orthogonal projection of p' on the line of nodes, and this (see figure) is equal to the sum of the projections of F′G and GT, where F′G is half the distance between the foci, and GT the line joining the foot of p' with the centre of the ellipse.

But the projection of F′G is equal to $a \cdot \cos\lambda$, and that of GT is equal to $a \cos(\theta - \lambda)$, θ being the true anomaly, so that we have

$$\pi V = \frac{la^2 \sin \gamma}{Pb} [e \cos \lambda + \cos (\theta - \lambda)],$$

$$\left.\begin{aligned} \text{or } \pi V &= A + B \cos (\theta - \lambda) \\ \text{where } A &= \frac{lae \sin \gamma \cos \lambda}{P\sqrt{1-e^2}} \\ \text{and } B &= \frac{la \sin \gamma}{P\sqrt{1-e^2}} \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots (\alpha)$$

A and B being constants depending only on the elements of the orbit.

If we wish to know at what time the value of πV reaches its maximum value for any particular binary pair we have to make

$$A + B \cos (\theta - \lambda) \text{ a maximum,}$$

or

$$\sin (\theta - \lambda) = 0.$$

Hence we see that, if we disregard the sign of V, the value of πV will be greatest when $\theta = \lambda$ or $\pi + \lambda$, or, as I showed otherwise in my previous paper, the relative velocity in the line of sight is a maximum when the body is passing through the line of nodes, and the first of equations (α) shows that its greatest value is $\pm A + B$, the upper or lower sign being taken according as λ is in the first or fourth, or in the second or third quadrants.

I may take this opportunity of saying that the method which computers of double-star orbits adopt of placing ☊ (on which the quadrant of λ depends) in all four quadrants is entirely misleading, as it is calculated to give the impression that there is some means of determining which is the ascending node from micrometric observations alone; whereas the fact is that we cannot from these data decide at which node the companion is receding from or approaching the Sun, nor is there even any convention as to which direction of motion should be implied by the term *ascending*. We can, of course, from micrometric measures fix the position of the *line* of nodes, but the longitude of the *ascending* node must always be doubtful to the extent of 180°, unless the spectroscope be employed and the resolved part of the velocity be sufficiently large to become sensible.

With regard to this point Villarceau, in his paper on double-star orbits, in the *Connaissance des Temps*, 1877, remarks:—"L'angle ☊ sera indéterminée à 180 degrés près. Cela doit être, puisque il est impossible de distinguer si le satellite en traversant l'un des nœuds s'écarte ou se rapproche de notre système solaire." Lower down he says: "Le signe de I" (the inclination of the orbit) "reste arbitraire. La longitude ☊, étant celle du nœud ascendant, est ambiguë, comme il vient d'être dit, et l'on peut toujours prendre I positif et compris entre 0 et 180 degrés. . . . L'hypothèse de I négatif change effectivement le nœud ascendant en nœud descendant." And, again, "La valeur de I . . . . restera affectée du double signe qu'on ne peut éviter."

Now, although this ambiguity is of no importance when we are concerned with only one particular binary system, and aim

only at predicting the distance and position of the pair for any given time, yet if we wish to draw general conclusions from the situations of a large number of groups, such, for the sake of illustration, as Mädler's conception of a "stellar equatorial plane," to which he supposes the planes of the double-star orbits to be approximately parallel, this ambiguity meets us at the very outset. If, for instance, we take the star *p Eridani*, and inquire how the plane of its orbit is situated with regard to the plane passing through *Procyon*, *Mira Ceti*, and the Sun, we shall find that we cannot tell whether it is approximately perpendicular or approximately parallel to it. Or if we compare the plane of the orbit of δ *Cygni* with that of the Earth's equator, we cannot determine whether it is inclined to it at an angle of 7 or of 82 degrees. The advantages, therefore, to be expected from spectroscopic, or rather spectrographic, observations of double stars for which πV is greater than 0·1, are

(1) An independent check on the parallax where this has been determined trigonometrically.

(2) A determination of the parallax where, owing to its smallness, the trigonometrical method fails.

(3) A determination of the sign of the inclination which will remove the ambiguity attaching to the situation of the orbit.

In Table I. below I give the elements of a number of orbits, and the values of A and B as computed from these elements. These quantities will enable us to compute the value of πV corresponding to any given time with the least possible labour, as it is only necessary to compute the value of θ for the given time, and to substitute the value thus found in the first of equations (a). In the last column of this table is given the greatest value to which πV can attain; and if it is required to ascertain at what epoch πV reaches its maximum value, it is only necessary to find the date corresponding to $\theta = \lambda$ or $\theta = \pi + \lambda$, according to the quadrant in which λ lies, as explained above. In Table II. will be found the values of πV for some of the most remarkable pairs, corresponding to the date 1891 0, and in those cases where the parallax has been determined I have added the value of V in the third column. It will be noticed that in the case of these stars, as might have been expected in consequence of their comparative nearness to us, the velocities are for the most part very small and such as direct eye-observations must fail to deal with. The success of Professor Vogel's method, however, and of the Henry Draper Memorial photographs, seems to hold out the hope that even velocities such as these may become sensible on the plates, and, in view of the very striking observations on ζ *Ursæ Majoris* lately published by Professor Pickering, it is not improbable that the highest velocities will be found, not in the wide and easy doubles, but in those close pairs such as δ *Equulei*, where, owing either to their remoteness or the smallness of the linear dimensions of their orbits, it is extremely difficult to divide the discs optically or to separate the two spectra on the photographic plate.

TABLE I.

Name of Star.	Magnitudes of Components.	Ω	γ	λ	e	a	P	T	Authority.	A	B	±A+B
		° ′	° ′	° ′		″	years.					
η Cassiopeiæ	4, 7½	33 20	48 18	196 7	0·624	8·639	+195·2	1902·0	Gruber	−0·469	0·782	1·251
36 Andromedæ	6, 7	57 54	41 39	142 19	·634	1·54	+349·1	1798·8	Doberck	−0·035	0·070	0·105
p Eridani	7, 7	81 42	44 40	327 15	·378	3·82	−117·5	1817·5	,,	+0·145	0·456	0·601
40 Eridani (B.C.)	9, 11	146 20	76 20	354 23	·136	5·99	−139·0	1863 9	Gore	+0·105	0·781	0·886
α Canis Majoris	1, 12½	45 27	58 37	136 39	·591	8·53	− 44	1889·4	Pritchard	−1·629	3·788	5 417
Σ 1037	7, 7	156 58	68 17	273 27	·632	0·182	− 15·0	1827·7	Mädler	+0 010	0·269	0·279
α Geminorum	2½, 3½	31 58	42 5	294 1	·344	7·5375	−996·9	1750 3	Thiele	+0·014	0·100	0·114
ζ Cancri	5, 5½	81 33	15 32	109 44	·391	0·853	− 60·3	1866·0	Seeliger	−0·010	0·076	0·086
Σ 3121	7½, 8	16 30	74 12	149 30	·26	[0·71]	+ 37·0	1842·8	Doberck	−0·079	0·353	0·432
ω Leonis	6, 7	148 46	64 5	121 4	·536	0·890	+110·8	1841·8	,,	−0·044	0·158	0·202
φ Ursæ Maj. = O.Σ.208	6, 7	105 18	57 57	72 7	·788	0·54	+115·4	1877·1	Casey	+0·029	0·119	0·148
γ Leonis	2, 3½	111 34	43 6	195 22	·733	1·98	+407·0	1741 0	Doberck	−0·066	0·090	0 156
ξ Ursæ Majoris	4, 5	100 13	56 40	125 0	·416	2·580	− 60·8	1814 5	Pritchard	−0·172	0·720	0 892
O.Σ. 235	6, 7	96 17	60 13	129 55	·587	1·066	+ 94·4	1839·1	Doberck	−0 084	0·224	0·308
γ Virginis	3, 3	33 35	35 6	283 44	·896	3·97	−185·0	1836·7	Thiele	+0·109	0·513	0·622

Name of Star.	Magnitudes of Components.		Ω		γ		λ		e	a	P	T	Authority.	A	B	±A+B
											years.					
42 Comæ Ber.	6,	6	10	30	90	0	99	11	·480	0″657	+ 25 7	1859·9	O.Σ. and Dubjago	−0·041	0·538	0·579
Σ 1757	8,	9	120	40	49	25	140	37	·623	2·13	+291·8	1792 65	Casey	−0·063	0·131	0·194
Σ 1819	8,	8	156	25	37	31	348	56	·305	1·46	−340·1	1797·0	„	+0·015	0·051	0·066
α Centauri	1,	4	25	47	79	32	54	47	·526	17·50	+ 77·4	1876 0	Elkin	+1·462	4·827	6·289
ξ Boötis	4½,	6½	26	22	36	55	117	46	·708	4·86	−127·35	1770·7	Doberck	−0·198	0 600	0·798
44 *i* Boötis	5,	6	65	29	70	5	1	18	·71	3·093	+261·1	1783·0	„	+0 207	0·292	0·499
η Coronæ Borealis	5,	5½	26	42	57	59	215	35	·2625	0·827	+ 41·6	1850·3	Dunér	−0·069	0·323	0·392
μ^2 Boötis	7,	8	166	7	35	12	40	54	·567	1·057	−266·0	1862·55	Pritchard	+0·022	0 051	0·073
O.Σ. 298	7,	8	14	38	56	10	342	31	·487	0·886	+ 68·8	1813·0	Doberck	+0 105	0·226	0·331
γ Coronæ Borealis	4,	7	110	24	85	12	233	30	·350	0·70	− 95·5	1843·7	„	−0·030	0·144	0·174
51 ξ Libræ	5,	5	12	15	68	42	89	16	·077	1·26	+ 95 9	1859·6	„	0·000	0·227	0·227
σ Coronæ Borealis	5,	6	16	27	31	56	73	51	·7515	5·885	+845·9	1826 9	„	+0·022	0·103	0·125
λ Ophiuchi	4,	6	88	40	21	27	151	0	·493	1·19	+240·95	1800·5	„	−0·017	0·038	0·055
ζ Herculis	5,	5½	41	44	43	14	252	45	·463	1·284	− 34·4	1864·8	„	−0 073	0·533	0·606
Σ 2130 = μ Draconis	5,	5	Indeterminate		0	0	Indeterminate		·493	3·38	−648·0	1940·35	Barberich	0·000	0·000	0 000*

* The position-angle of periastron is 275° 26′.

Name of Star.	Magnitudes of Components.	Ω	γ	λ	e	a	P	T	Authority.	A	B	±A+B
		° ′	° ′	° ′		″	years.					
Σ 2173	6, 6	152 39	80 53	7 16	·135	1·009	− 45·4	1872·9	Dunér	+0·055	0·409	0·464
μ^2 Herculis	9½, 10½	57 57	60 43	156 21	·302	1·46	+ 54·25	1877·1	Doberck	−0·126	0·455	0·581
τ Ophiuchi	5, 5½	67 1	46 8	36 26	·6055	1·193	+217·9	1818·5	„	+0·045	0·092	0·137
70 *p* Ophiuchi	4, 6	127 23	58 5	151 55	·467	4·790	− 94·4	1808·9	Pritchard	−0·370	0·839	1·269
ζ Sagittarii	6, 9	83 22	58 48	263 21	·170	0·53	− 18·7	1882·9	Gore	−0·009	0·455	0·464
γ Coronæ Australis	5½, 5½	49 9	68 38	255 24	·699	2·400	− 55·6	1882 8	Schiaparelli	−0·183	1·039	1·222
δ Cygni	3, 8	91 8	37 46	203 2	·286	2·310	−415·1	1904·1	Behrmann	−0·017	0·066	0·083
β Delphini	3, 11	10 56	61 35	220 57	·096	0·460	+ 16·955	1868 85	Celoria	−0·040	0·556	0·596
λ Cygni	5, 6	105 18	58 48	139 6	·602	0·602	− 93·4	1926·9	Glasenapp	−0·058	0·128	0·186
4 Aquarii	6, 7	340 14	56 37	235 0	·461	0·717	−129·8	1752·0	Doberck	−0·025	0·096	0·121
61 Cygni	5, 6	340 3	71 25	271 33	·534	30·42	+523	1834·8	Peters (Provisional)	+0·017	1·204	1·221
„	5, 6	341 4	63 55	278 16	·174	29·48	+782·6	1834·8	„ (Final)	+0·016	0·635	0·651
δ Equulei	4½, 5	24 3	81 45	74 1	·201	0·406	− 11·478	1892·0	Glasenapp	+0·037	0·660	0·697
τ Cygni	5, 8	83 0	44 40	205 26	·3475	1·19	− 53·9	1864·0	Gore	−0·096	0·306	0·402
ζ Aquarii	4, 4	140 51	44 42	134 40	·652	7·64	−1578·8	1924·15	Doberck	−0·038	0·083	0·121
Σ 3062	7, 8	38 35	32 11	92 7	·461	1·27	+104·4	1834·9	„	−0·002	0·135	0·137

Table II.

Values for 1891·0.

Name.	πV	V	π and Authority.
			"
η Cassiopeiæ	−0·348	2·3	0·15 O.Σ.
36 Andromedæ	+0·034		
p Eridani	−0·305		
α Canis Maj.	−5·326	13·4	0·39 Gill and Elkin.
Σ 1037	+0·151		
α Geminorum	+0·112	0 6	0·20 Johnson.
ξ Ursæ Maj.	−0·294	7·4	0 04 Klinkerfues.
γ Virginis	+0 076		
α Centauri	+2·741	3 7	0·74 Gill and Elkin.
ξ Boötis	+0·372		
44 i Boötis	−0·082		
η Coronæ Bor.	−0 352		
51 ξ Libræ	+0·184		
ζ Herculis	−0·325		
70 p Ophiuchi	+0 197	1·2	0·16 Krueger.
γ Coronæ Austr.	+0 698		
Σ 2173	−0·327		
O Σ. 235	+0·076		
61 Cygni	−1·173	2·5	0·47 Ball.
,,	−0 285	0·7	,, ,,
ζ Aquarii	+0 041		

On some Celestial Photographs made with a large Portrait Lens at the Lick Observatory. By E. E. Barnard, M.A.

Professor Holden having secured for the Lick Observatory a very large portrait lens (maker, Willard, New York, 1859), I have taken advantage of the opportunity to make with it some experimental long-exposure negatives of the Milky Way, the great nebula of *Andromeda*, and the *Pleiades*. This lens, with the diaphragm removed, has an equivalent aperture of 5·9 inches, and a focal length of 31 inches.

The lens was mounted temporarily in a rough wooden box, and before beginning work the stellar focus was accurately determined by a series of exposures on *Polaris*, &c.

The camera was then strapped firmly upon the tube of the $6\frac{1}{2}$-inch equatoreal, which, with a high power, was used as a following telescope. This instrument, having slow-motion rods in right ascension and declination at the eye-end, was specially

suited for controlling the motion of its clock, which with the additional weight of the camera required careful and constant attention.

Three negatives of different parts of the Milky Way were made. The cluster M. 11 occupied the centre of one of these plates; another plate covered the region $\alpha = 18^h\ 0^m$, $\delta = -19°$; while the third—in many respects the most remarkable of the Milky Way plates—was in $\alpha = 17^h\ 56^m$, $\delta = -28°$.

This last plate shows an object that I wish to call attention to. For many years I have observed in my comet seeking a most remarkable small inky black hole in a crowded part of the Milky Way. This singular object, with one or two faint stars in its following part, is in about $\alpha = 17^h\ 56^m$, $\delta = -27°\ 50'$ (see *A. N.* 2588, where I have called attention to it). I have not seen this black hole mentioned anywhere. It is about 2′ in diameter, slightly triangular, with a bright orange star on its n. p. border and a beautiful little cluster following. There are other dark holes and vast gaps near this, but nothing so remarkable in the entire circuit of the Milky Way. On the night of August 11 I made a negative of this region—the black hole occupying the centre of the plate—with the intention of showing the hole and the singular configuration of the Milky Way at that point. An exposure of $3^h\ 7^m$ was given, a following star being kept constantly bisected by cross wires in the eyepiece. Not only is the black hole clearly shown in this negative, but the entire cloudlike formation about it with myriads of stars are all faithfully depicted. The exceeding beauty of a glass positive from this plate is beyond description. The other two negatives of the Milky Way are as fine as this, but the Milky Way itself is not so grand.

A negative of the *Pleiades* on August 23, with an exposure of $1^h\ 13^m$, shows the *Merope* nebula quite conspicuously, the small sharp projection of nebulosity from *Electra*, and some of the nebulosity about *Maia* and *Alcyone*. The *Pleiades* at this time, however, were very poorly placed for photographing.

Two negatives were made of the great nebula of *Andromeda*, with exposures of $3^h\ 15^m$ and $4^h\ 18^m$. Throughout these exposures, as in the other cases, the eye was kept constantly fixed on a star bisected by cross wires in the eyepiece, and the clock controlled by the slow-motion rods. Both negatives clearly show the dark spaces and the nebulous rings that were first shown to exist by Mr. Roberts in his exquisite photographs of this nebula. The rings of nebulosity are seen at a glance, though the image on my negatives is on a small scale, the full extent of the nebula covering one inch. I have tried to see these with both the 12-inch and the 6½-inch, but without success, though the so-called "canals" on the north side are clearly seen in both instruments.

In studying the distribution of the stars in space and the structure of the Milky Way, it is clear that any legitimate means of exaggerating peculiarities, or rather of bringing them out

more strikingly, is greatly to be desired. It would appear that the best way to do this is to photograph large areas of the sky so as to include enough material. If now we reduce this to a small scale, relations that would otherwise escape the eye are brought prominently forward. Acting upon this idea, I have made reduced copies of the above negatives. The result is striking. In the Milky Way pictures the cloudlike masses of stars stand out more boldly, and their forms are more definite than in the original. Reduced in this way, the picture of the region of the *Andromeda* nebula is singularly beautiful; and it shows in a most remarkable manner the peculiar structure of that part of the heavens. The intricate arrangements of the stars in rings and segments are thus shown as nothing else can show them.

Previous to these experiments, at Professor Holden's suggestion, I had attempted to photograph the Milky Way with a 1-inch (9 inches focus) Voigtländer lens, mounted on the 12-inch and the 6½-inch telescopes at different times. These exposures—running up to an hour and a half—showed absolutely no trace of the cloud-forms that are so striking to the eye. The plates were, however, literally sprinkled with stars, most of which were beyond the reach of the eye alone, and therefore much less bright than the Milky Way itself. The sensitive plate was not deceived by a quantity of light as the eye was; but as its action depends upon the intensity of the light, it had gone to work systematically to pick out the individual stellar points of the Milky Way. Of course we know if it had had time enough it would have finally begun the impression of the luminous groundwork. Nothing could show more beautifully the difference between intensity and quantity in the action of light upon the sensitive plate than these attempts to photograph the Milky Way.

With the Willard lens, which gave essentially thirty-six times as much light for the stars and three times that for the Milky Way, considered as a surface, three hours were required to show the cloud-forms.

Upon examining these plates, especially the one in $17^h\ 56^m$ $-28°$, it will be seen that we have here opened up for us a magnificent field of investigation. It is only necessary to mention the very great differences in the delineation of even the more conspicuous parts of the Milky Way, as shown on different star charts, to see that we have not the means in such charts to make anything like a comprehensive study of the Milky Way. Eyes differ so much, and astronomers, as a rule, are such very poor artists, that we may never expect to get anything like a fair delineation of the Milky Way by the human hand alone; and if we could, the human eye is too feeble to grasp the more important details, and the largest field of any telescope is too small to trace such large features with any accuracy. Observing and charting the stars does not aid us at all, for the true form of the Milky

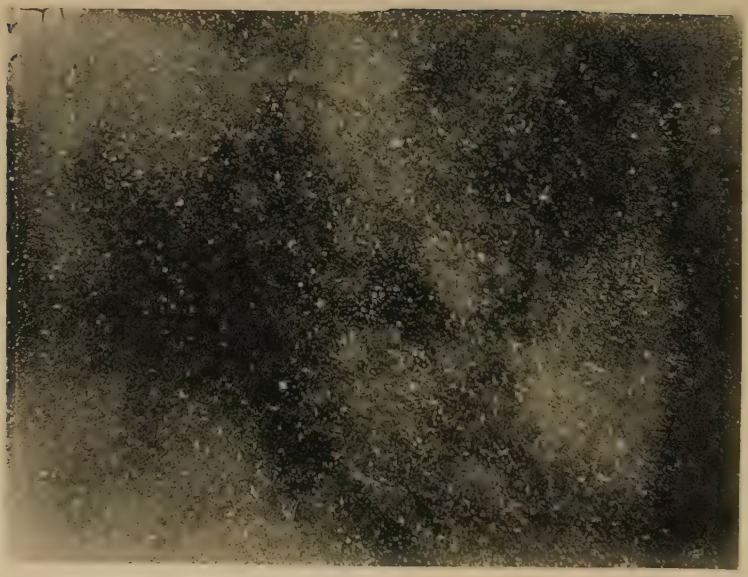


Fig. 1. R.A. 17h. 56m. Decl. −28°, 1889, Aug. 1, 8h 56m. to 12h. 3m. (1 in. = 1°·8).

Fig. 2. M. 31. 1889, Aug 26, 8h. 8m. to 12h. 25m. (1 in. = 1°·8).

Way does not depend on stars as bright as the ninth and tenth magnitude, but upon the millions of smaller stars, most of which are beyond the reach of any telescope. The photographic telescopes that are now being made—except, indeed, the Bruce telescope—will give us very little information about the structure of the Milky Way, as the field of view will be too small, and they will not show the cloud-forms.

What is wanted, therefore, is a photographic chart of the Milky Way made with a short-focus lens of the largest attainable aperture—one that will cover a field of at least one hundred square degrees—with an exposure time that will show the luminosity of the Milky Way. Such a chart can easily be made in one year's time, and must be of inestimable value. I am happy to make the first contribution to such a map.

I hope when the 6½-inch returns to the observatory to be able to resume the photography of the Milky Way.

The success of these long exposures suggests the possibility of extending the time of exposure through several successive nights, the same following star being used night after night, the plate remaining undisturbed, but carefully protected from light during the day.

I take pleasure, through the courtesy of Professor Holden, in presenting to the Royal Astronomical Society some glass positives of these negatives, and also an album with silver prints, both negative and positive, from the same.

Descriptions of the Photographs and Positives.

R.A. $18^h\ 0^m$—19°. Album, pp. 4 and 5. 1889, July 28.—This is a remarkable region, but the exposure was too short to show it well, clouds having interfered. The adopted time of exposure is $1^h\ 17^m \pm$, with the aperture reduced to 4 inches.

The striking feature about this region is a series of vacancies that are fairly well shown in the print just below the dense mass of stars (p. 5). Another striking feature is the presence of a great many stars with ellipses, or partial ellipses, of small stars about them, the larger star apparently occupying the focus of the ellipse. One of the three large stars (p. 5) to the left (south) on the picture is a good example of this. The *Omega* nebula is shown on this print, to the right near the edge. In connection with this picture it is well to read Secchi's remarks on this same region, as given by Webb, *Celestial Objects*, p. 385, 4th edition.

Region near M. 11. Album, pp. 2 and 3. 1889, August 2, from $11^h\ 8^m$ to $13^h\ 53^m$.—Here the cloudlike forms, partially resolved into stars, are finely shown. M. 11 is placed on the extreme N. edge of the connecting mass that extends between two vast clouds of stars.

R.A. $17^h\ 56^m$, $\delta = -28°$. Album, pp. 1, 6, 7. 1889, August 1, $8^h\ 56^m$ to $12^h\ 3^m$.—This remarkable picture shows the cloud-

forms like waves of spray. A dark curving lane runs from the lower left-hand portion of the picture, p. 6 (S.W.), and curves gracefully upwards to the place of *Jupiter*. It is singularly like the stem of a great leaf. At the middle of the picture it is seen to pass behind some of the clouds of stars and emerge beyond, showing us clearly which part of the Milky Way at that point is nearest to us. Imagination may aid one, but it looks as if the lines of the cloud-forms, and of the stars and vacancies, all run more or less concentric with this extensive lane. In the reduced glass positive, this lane and its connecting branches come out grandly (the glass positives should be examined with the light of a lamp through a white porcelain shade, or against the sky away from the region of the Sun). In this positive the masses of stars to the north-west of the middle resemble breaking spray. The black hole is seen slightly to the left of the centre, with the small cluster as a white spot close to the right of it. The planet *Jupiter*, at the top of the picture (not shown in the plate), is very large, from the excessive over-exposure, and mingles its light with that of the trifid nebula (Fig. 1, plate 3).

The Great Nebula of *Andromeda*. Album, pp. 8, 9, 10, 11. 1889, August 26, $8^h\ 8^m$ to $12^h\ 25^m$.—I would call special attention to the *negative* print on p. 10, where the entire 8×10 negative is reduced to a scale of $5°{\cdot}3$ to the inch. Above the preceding end of the nebula, and apparently connected with it, is a diffusion of light for some five degrees to the north-west, that looks very much like nebulosity. That this is real nebulosity I am somewhat doubtful. Yet the appearance is singularly real. It is possible that this is a reflection from the lenses, in some manner due to the very long exposure ($4^h\ 18^m$ of sid. time). It has not been possible for me to verify it by repeating the exposure, but if it is true nebulosity, this plate will have been the first to show it (Fig. 2, plate 3).

It is needless to call attention to the remarkable structure of this part of the sky, as shown on this reduced picture, in contrast with that shown, say at $17^h\ 56^m$—28°. The singular lanes of vacancies to the north-east of the nebula (p. 10) are so striking that the eye catches them at once. By carefully counting areas, I have estimated that there are 64,000 stars distinctly visible on the original 10×8 plates of this region.

It is unnecessary for me to go into any further description of the arrangements of the stars in these negatives, as that has already been thoroughly done by Professor Holden, in his communication on the subject. (See *Monthly Notices*, vol. l. p. 61.)

Mount Hamilton:
1890 *January* 1.

Photograph of the Clusters 33 *and* 34 H VI. *Persei.*

By Isaac Roberts.

The two well-known clusters in the sword-handle of *Perseus*, when seen on a photograph which has been exposed in a 20-inch reflector for three hours, present an appearance of grandeur that can only be fully realised by aid of the photographic method. The enlargement from the negative taken on January 13, 1890, is now before us, and any written description will convey only a very inadequate idea of it. The stars are densely crowded in the clusters, as well as in the surrounding and intervening spaces, and by looking at the photograph from a distance of about 18 inches from the eye, the festoon-like groupings of the stars are very striking; but at present I only attach to these combinations a fortuitous character, for we well know by experience that the eye readily sees patterns and groupings on any surface that is made up of a large number of small pieces in close contiguity. This general statement is not intended to exclude the possibility, or even probability, that numerous stellar systems will in time be found amongst the various star groups shown on photographs.

The clusters here referred to differ in character from those like the *Pleiades*, 13 *M. Herculis*, or 2 *M. Aquarii*, inasmuch as there is no trace of nebulosity shown in either of them; the component stars show on the negative as clear discs from the circumference to the centres of the two clusters, and this fact, when it is considered in connection with the nebular or the meteoritic hypotheses, suggests a relative progression in the evolution of some of the nebulæ and clusters which have already been photographically delineated and presented to the Society. For instance, the nebulæ in *Orion* and in the *Pleiades* have not yet assumed a symmetrical form like the nebulæ in *Andromeda*, in *Ursa Major*, and in the spiral nebula in *Canum Venaticorum*. These latter would therefore, on this hypothesis, be anterior in time, or have proceeded further in their development towards the formation of stellar systems, than the nebulæ in *Orion* or in the *Pleiades*.

The clusters 13 *M. Herculis*, 5 *M. Libræ*, and others, have still further than those of the *Andromeda* type developed into stellar systems, for the nebulosity remaining in them is faint and limited within the boundary of the clusters, and so approaches the period of total absorption. Again, we see the clusters in *Perseus*, now introduced, appearing to be quite free from nebulosity, and therefore, by this hypothesis, are anterior in time to any of the other nebulæ or clusters which have been referred to. We seem to be thus on the way, by the aid of photography, to an intelligible classification of some of the stages in the evolu-

tion of the universe, but of course we must proceed with caution and refrain from dogmatising. Our data are as yet limited, though of a striking character, and I shall at present be content with offering these suggestions, and continue to seek for further evidence, which in our dull climate is only to be obtained by much wearisome watching and promptness in grasping any opportunity.

Suspected Variability during Short Periods in certain Stars in Orion.
By Isaac Roberts.

The evidence of variability in some of the faint stars in *Orion* at present rests upon a photograph which I took with a dual exposure of the plate. The first exposure was of two hours' duration on January 29, and the second of $2\frac{1}{2}$ hours' duration on February 3, 1889, and on the enlarged copy of the photograph which I now present to the Society is shown the stars referred to, inclosed within a white ring, in order readily to distinguish them. The enlargement was made direct from the negative under the direction of Mr. Lockyer by his assistants at the Normal School of Science, South Kensington Museum. On examination of the dual stellar images on the photograph the eye immediately detects that ten of them have undergone considerable change in brightness or magnitude during the interval of five days which elapsed between the two exposures. In three of the ten stars, the brightness has increased to the extent of from one-fourth to one-third the measured diameter of the stellar photo-image, and one star appears on the second exposure where none is shown on the first exposure. Six of the ten stars have diminished in brightness during the interval to the extent of from one-fourth to four-tenths, the measured diameter of the photo-image. The following table gives the positions by Bond's chart and the measured photo-diameters of the ten stars :—

Table of the Positions by Bond's Chart and the Measured Diameters on the Photographic Negative of Variable Stars in the region of Theta Orionis.

No. of the Star on the Enlarged Photograph.	Approximate R.A. from θ^1 −Preceding +Following.	Approximate Declination from θ^1 −South +North.	Measured Photographic Diameters of the Ten Stars in parts of an inch. 1889, January 29.	1889, February 3.	Star Magnitude by Bond.	Deduced Variation in Magnitude from Columns 4 and 5 in this Table in parts of an inch. Increase.	Decrease.
	m s	′ ″					
1	−0 38	−42 20	0·00479	0·00629	7th	0·00150	...
2	−0 20	−23 15	680	406	14th	. .	0·00274
3	−0 5	−23 15	499	613	12th	114	...
4	+0 32	−26 15	634	477	14th	...	157
5	+1 44	− 0 30	712	427	15th	...	285
6	+2 17	+11 0	622	500	not on chart	...	122
7	−0 25	+19 45	475	603	14th	128	...
8	+0 21	+17 15	535	351	not on chart	...	184
9	−0 3	+37 45	no star	490	15th	490	...
10	−0 9	+55 31	698	558	13th	...	140

I have with due care examined the film of the negative under the microscope in order to see if any defect or evidence of defective sensibility on parts of the film could be traced so as to account for the variability in the brightness of the stellar images, but I could not find any such evidence, and I would of course have repeated the photographic experiment if the state of the sky at any time during the past twelve months had permitted. Those who possess the necessary telescopic power may study by eye-observations the variability in these stars, and it is one of the functions of the photographic method to point out where eye-observations can with advantage be applied in search for special knowledge, and these ten stars are now indicated for that purpose.

Observations of the Variable Star S (10) Sagittæ.

By J. E. Gore.

The following are my observations of this short-period variable during the year 1889. They form a continuation of the observations given in *Monthly Notices* for March 1889.

The comparison stars are as before.

	Mag.
11 Sagittæ	5·8
DM. + 16°, 4086	7·0

Date.	Dublin M.T. h m	Mag.	Date.	Dublin M.T. h m	Mag.
1889 Jan. 1	7 30	5·8	1889 Oct. 15	10 12	6·13
May 24	10 10	5·7	16	7 35	6·16
June 3	10 40	6·28	17	10 27	6·4
July 15	10 38	6·24	22	11 15	5·75
29	10 0	5·8	23	7 55	5·7
30	10 10	5·8	24	6 40	6·0
31	9 35	5·9	26	6 35	6·34
Aug. 3	10 35	6·4	28	6 35	5·9
11	10 45	6·4	(30	6 37	5·75
20	9 55	6·45	)30	10 45	5·7
24	9 5	5·8	Nov. 5	7 35	5·9
30	8 30	6·2	16	6 50	5·8
31	11 15	5·7	19	9 30	6 15
Sept. 4	9 0	6·3	23	5 35	5·8
8	8 10	5·8	25	7 14	5·75
22	10 50	6 52	28	7 8	6·24
24	10 15	5·9	Dec. 5	7 29	6·13
25	8 30	5·7 (?)	11	7 58	5·7
Oct. 7	9 2	6·2	13	5 35	5·97
11	10 33	5·8	18	5 27	5·6
12	7 37	5·8	20	7 40	5·8
(13	6 40	5·8	22	6 10	6·08
)13	10 47	5·8	24	5 52	6·28

The observation of December 18 was near the maximum epoch No. 567, reckoning from an assumed maximum observed by me 1876 December 14.

Some Experiments relating to the Method of Obtaining the Coefficient of Absorption of the Wedge Photometer. By Edmund J. Spitta.

In a paper read before the Society in November 1887, on 'The Appearances presented by the Satellites of *Jupiter* during transit,'* attention was called to the discordant figures obtained when photometrically comparing a point of light, such as, for example, is exhibited by the stars, with an object of sensible area such as *Jupiter*. For the past two years or more an extensive series of experiments with the wedge photometer has been in progress, with the object of ascertaining the cause or causes of such discordance; but the subject has extended itself so much further than was anticipated, that it will be convenient to describe the results under three heads: (i) Those connected with the constant of absorption of the wedge photometer; (ii) the objections to employing such a form of photometer when dealing with objects of sensible area and the means devised to remedy the same; and (iii) idiosyncrasies in the photoperceptive faculty of the eye when viewing different sized areas. The object of this communication is to set forth the experiments connected with the first division of the subject only—viz., those concerning the constant of absorption of the wedge photometer, with a suggestion for an improved method of obtaining the same.

In the course of some experiments made at an early stage of the inquiry, with light of varying but known intensity, a suspicion was raised that the results obtained by the method of wedge extinction were incorrect. This suspicion was entertained both with experiments made on points of light, and areas of equal diameters but of different degrees of illumination.

The readiest means for the complete examination of this question was evidently to conduct the experiments in such a manner as to ensure the addition of a known quantity of light to the point or area under examination. In my earliest experiments I arranged three gas burners in an equilateral triangle, any or all of which could be made to illuminate a small disc of cardboard equidistant from the three, and similarly situated with regard to the gas burners. The wedge was used without a telescope, though a telescope tube was found convenient both to carry the wedge and give the means of easy direction. The intensity of the illumination of the cardboard disc by each of the gas burners was first examined and made sensibly equal, and then the intensity of the illumination when increased by the

* *Monthly Notices*, vol. xlviii.

addition of each of the gas jets in turn was carefully determined by the method of wedge extinctions. Although it seemed certain from the precautions taken that when the combined light of the three gas jets was allowed to fall on the cardboard disc that this disc was illuminated by a light three times that which it exhibited when illuminated by only one, yet the indications of the photometer showed that the light of the disc was that which would be given by three and a half burners.

A repetition of the experiment under slightly different circumstances, and made with another apparatus, constructed, if possible, with still greater care, showed the same amount of error, and in the same direction. It was therefore determined to conduct the experiments on a larger scale—*i.e.*, with greater range of illuminating power, in which the errors of observation could not have so large a proportion to the final result. With this view, an argand burner was firmly fixed on a solid horizontal board provided with cross pieces to prevent warping. Around it at equal distances, but on another board placed at right angles to the first, was arranged a series of twelve 1-inch mirrors, each being provided with a ball-and-socket-joint to allow of the necessary accuracy of adjustment in the subsequent equalisation of the lights. The reflected light from every mirror passed through a separate hole in another board placed between the lamp and the disc, and every aperture was provided with an accurately fitting wooden shutter. The mirrors were entirely enclosed during the final measurements, the room being carefully darkened. The preliminary adjustment of the mirrors led to the rejection of four, because they reflected a smaller amount of light than the others, due to their position relatively to the lamp. One of the mirrors having been arbitrarily selected as the standard, the light from each of the others was made equal to it within the errors of observation. This will be seen from the following table, which gives the intensity of the illumination of the cardboard disc when the light from each of the mirrors was allowed to fall on it in succession. Calling the light—nominally converted for convenience into magnitude—of the standard mirror (1) L, that of each of the others proved to be:—

Table I.

No.	Mag.	No.	Mag.
2	L−·042	6	L−·014
3	L−·092	7	L+·092
4	L−·075	8	L+·014
5	L+·075		

Before quitting the subject of adjustment, it may be remarked that, whatever difference may have previously existed in the reflective power of the mirrors, whether it arose from the silvering or from their position with respect to the lamp, is of no moment,

seeing that their light as reflected from the disc and viewed in the wedge photometer had been made as nearly equal as possible; and further, the light of the lamp is eliminated. All that is necessary was to ascertain that the light of the lamp did not vary during each series of observations, and this was readily effected by watching the light of the disc when illuminated by the mirror chosen as the standard.

The experimental measures were then commenced, the mirrors being numbered from one to eight. The mean extinction of the standard was first obtained, shutter two then opened and the increase of light measured, shutter three next, and so on to the end of the series. On a subsequent night the whole of the observations were repeated, but this time the conjoint illumination from the first and eighth mirrors were compared with the standard to obtain the increase of light reflected by two mirrors, adding the value of the seventh to arrive at the increase afforded by three and so on, by which means it was thought that the possibly slight inequality of the illuminating power of the mirrors would be eliminated, the small discrepancies shown in Table 2 being attributed to the unavoidable errors of observation which they do not exceed.

Table II.

No.			
2	·76	·075	2·01
3	1·33	·05	3·40
4	1·85	·10	5·50
5	2·21	·04	7·66
6	2 44	·045	9·46
7	2·77	·08	12·83
8	3·03	·025	16·30

In column 1 is shown the number of mirrors employed, in other words the intensity which the wedge photometer must exhibit, if properly evaluated. Column 2 the difference in magnitude actually obtained by the wedge. Column 3, the probable error of this in magnitude, and column 4 the successive increase in light derived from the magnitude given in column 2.

It may be here stated that these figures were not hastily accepted, in fact not until every possible source of error that could be thought of, such as the effect of fatigue of the eye, sudden alterations in the pressure of the gas, the effect of using large or small discs, had been eliminated.

Two remarks, however, are naturally suggested by a consideration of this table. First that the increase in the amount of light as shown in column 4 does not appear to take place with the regularity which the addition of equal increments of light seems to demand. But this difference is in a sense more apparent than real, arising from the necessary employment of a logarithm to convert the observed magnitudes into light-ratio. The point which is insisted on is that every addition of a unit of

light is accompanied by an observed result greater than the unit. The second remark is this ; that apparently, and as far as the table is concerned, a factor for the conversion of magnitude into light-ratio other than the conventional ·4 might be chosen which would satisfy the condition observed. Practically, if ·3 were taken, or if it were assumed that the light of each magnitude were double that of the one preceding, a tolerable agreement might be effected ; but this is impossible because in the determination of the constant of absorption of the wedge, the factor (·4) has been employed, owing to the original determinations having been made in light, and the differences in magnitude deduced by the convention.

A satisfactory explanation of the result arrived at in Table II. is not easy. The most plausible was that some error had been made in the evaluation of the wedge, or else that its absorbent properties had undergone some change after the numerous extinctions with which it had been employed in the *Jupiter* experiments. Accordingly resort was made to the method of evaluation as adopted by Professor Pritchard and explained by him in his Memoir on the wedge photometer,* and which is dependent upon the physical nature of polarised light. After acquiring a reasonable familiarity with the polarising apparatus, a determination of the coefficient of absorption over different portions of the wedge was effected and the result compared with that obtained by Mr. Plummer, who had kindly made the one used in the results given in Table II. It was found the two determinations were almost identical, the discordance not exceeding ·06 magnitude. This at once set aside the question of possible error in the evaluation, and proved that the wedge had not undergone any change from age and use. The only point to which it seemed that objection might yet be made in these experiments, was the employment of a disc which of necessity occupied some area on the wedge when undergoing extinction. The use of a point of light would vary the conditions somewhat under which the experiments had been made, and more nearly resemble the observations made on stars. By using an artificial star, which was effected by illuminating one of the small holes mentioned in the *Jupiter* experiments,† and controlling the light issuing through it by an Abney photometer, the following series of measures was obtained :—

Table III.

No.			
2	·92	·007	2·33
3	1 34	·035	3·43
4	1·63	·063	4·48
5	2 26	·021	8·05
6	2·36	·085	8 80
7	2·81	·028	13·31
8	3·03	·016	16·30

* *Memoirs R.A.S.*, vol. xlvii.

† *Monthly Notices*, vol. xlviii., and *The Observatory*, vol. x.

The arrangement of the figures in this table is precisely the same as in Table II.; and in estimating its accuracy or its apparent deviations from uniformity the remarks made on that table must be rigidly borne in mind. As a general rule, it will be seen that the resulting magnitudes of column 2 do not differ in the two tables by quantities much greater than those shown in the probable errors. The observations were thought to be easier for the brighter lights, or at least left a more favourable impression in the observer's mind, and in the case of the full brilliancy of eight lights the coincidence is exact. The interest is not lessened by the consideration of the fact that in the first set, reflections off a disc of sensible area were employed, but in the second, the augmentation in intensity was effected in a point of light.

At this juncture an opportunity occurred of testing another wedge by the polarising method, one made precisely after the model of that used by Professor Pritchard. The constant of absorption, carefully determined, gave a ratio of 1 :16·40 instead of the real ratio of 1 : 8 which strikingly corresponded with the 1 : 16·30 obtained with the Clapham wedge, which was of a shorter and consequently steeper make, or one where a denser pigment had been employed in its manufacture.

As no solution of the difficulty presented itself, suspicion was attached to the accuracy of the sine law of Malus,* which underlies the polarising method adopted by Professor Pritchard, or rather, admitting the theoretical accuracy of the law, it did not seem impossible that the practical application of it might be attended with difficulties, and an unsuspected systematic error vitiate the results arrived at by its use. I proposed accordingly to test the practical application of the law by means of the Abney photometer; but the matter led to a protracted series of experiments, their entire discussion forming the subject of a paper communicated to the Royal Society by the kindness of Captain Abney, and read in June 1889, from which the substance of what follows is extracted. Before, however, giving a brief account of the experiments themselves, the precautions taken with them, and the results derived therefrom, it is necessary to hastily state the principle of the process employed by Professor Pritchard. If a Nicol's prism, capable of turning freely about its axis, be attached to a double-image prism, and two illuminated apertures (narrow rectangular slits are employed by Professor Pritchard) be viewed through this apparatus, there will be seen, as is well known, owing to the employment of the double-image prism, two images of each aperture, which can be successively made, by turning the Nicol through a definite angle, fainter and fainter till final disappearance of one pair of images supervenes. If the Nicol be furnished with the means of recording the angle through which it is turned, and (η) be the reading for the dis-

* Paris Académie des Sciences. *Mémoires présentées par divers Savants*, tome 2, 1811.

appearance of one of the images, and (q') be the reading for another position of the Nicol, then the brilliancy of the object (P) will be expressed by $P \sin^2 (q'-q)$, and $P \cos^2 (q'-q)$. Similarly, the brilliancy of the second object or aperture Q will be expressed by $Q \sin^2 (q'-q)$, and $Q \cos^2 (q'-q)$. Whence, making the images derived from the *extraordinary* ray of P equal to that produced by the *ordinary* ray of Q, the ratio of the light of P to Q will be expressed by

$$\tan^2 (q'-q).$$

Practically it is convenient, owing to the difficulty in determining the precise angle at which the extinction of either ray occurs, to observe equalities of brilliancy on each side of the zero, and this is the method which Professor Pritchard has adopted for determining the absorptive power of a medium, by placing a certain portion of his wedge behind the rectangular apertures already mentioned, and measuring by the method indicated the ratios of the light transmitted through those two portions, the distance between which is carefully measured. It was originally intended to employ in these experiments the method just described in evaluating the constant of absorption of the wedge, but an objection presented itself, for the two images not under examination were never of equal brilliancy whilst the observation for equality in the other two was being effected. If small differences of intensity were being compared (as for instance in evaluating the wedge) this was of no consequence, but when illuminations of greatly different intensity were employed, the disturbing effect was so distracting, that it was felt grave doubts as to the accuracy of the observations might be justly entertained. It was determined therefore to modify the arrangement by using a single slit, Captain Abney's photometer being so arranged as to diminish at will the illumination of either ray. The figures obtained varied considerably, the observations being characterised by a large observational error, but the ratio indicated by the polarising apparatus *was always greater* than that shown by the Abney photometer. Much larger prisms were then obtained, and a more perfect apparatus constructed, the images being focussed by a lens across a portion of the observatory on a screen, the observer being surrounded by an improvised wall to secure darkness during the subsequent equalisation of the lights. Still the same result was manifest, the ratios exhibiting the same peculiarity as in the earlier experiment, although be it noticed the observational errors were much smaller. The assistance of a friend well accustomed professionally to the equalisation of lights was then sought, but the independent measures by him again supported the previous experience. To find out the cause or causes of this discrepancy between the ratios obtained and those known to exist, became the subject of a most protracted inquiry, but after eliminating all possible causes of error in the apparatus, such as might occur from irregular illumination of

the slit, deviation in position of the lamp employed from night to night, eccentricity of the Nicol, different absorptive power of the two halves of the double-image prism employed, condition of the lens used to focus the images on the screen, positions of the prisms with respect to the line of collimation, and the possible fluorescence of the material employed in the manufacture of the screen, a suggestion due to Captain Abney, it was ultimately found to be due to *polarised reflections from the inner surface of the Nicol's prism*: rays which were found to utterly prevent the correct equalisation of the images, either by augmenting the angular reading in one position of the Nicol or detracting from it in the other. After some time, the effect of these reflections was discovered to be completely eliminated by the use of a diaphragm, placed between the eye and the Nicol, for after the employment of such, the ratios came out reasonably accordant with those known to exist, as the following table, extracted from the paper in question, fully shows:—

TABLE IV.

Known ratios.	Obtained by experiment.
1 to 2	1 to 2·14
3	3·02
4	3·84
5	4·97
6	5·80
12	11·97
18	17·11*

The crucial test, however, of the truth of the assertion that the cause of the increase in the coefficient of absorption, as obtained by Professor Pritchard's method, lay in the fact that the polarised reflections from the internal surface of the Nicol were not cut off by a suitably adjusted diaphragm, yet remained to be proved. For this purpose the rays issuing from the Nicol having been focussed on the screen, and the precautions mentioned above having been most carefully introduced, a fresh evaluation was made of the wedge, when the resulting coefficient closely accorded with that obtained by both the previous apparatus, as the following table clearly exhibits:—

TABLE V.

	Mag.
By the method of reflection from mirrors	·596
By the employment of Abney's photometer	·588
By the polarising method WITH diaphragm	·580
(By the polarising method WITHOUT diaphragm ...	·71)

* The cause of the falling off in this particular ratio is duly accounted for.

It may seem to those who are not engaged in practical photometry that the employment or non-employment of a diaphragm is a very small matter, but that would be altogether to underrate its importance. My real object in communicating the results of these experiments to the Society is to point out the undesirability of employing a method of evaluating which without great precautions is likely to lead to uncertain results. Initially the method, as hitherto practised, is open to a further objection, that the difference of the intensities of light compared by means of the polarising apparatus *must be small*; that is to say, the rectangular slits must be near together. In Professor Pritchard's case, the distance between the slits was ·38 inch; and though no doubt his caution and experience enabled him to reduce the error of the determinations of the constant to a minimum, yet it is nevertheless the fact that if the difference of wedge reading be 3·8 inches, this error, however small, must be multiplied by ten. An advantage of the polarising method, which must not be lost sight of, is that it offers a very ready means of examining the *uniformity* of a wedge, far more so, indeed, than any other with which I am acquainted. If the intensities at any two places on the wedge be equalised by a certain position of the Nicol, then that same equalisation *must* be maintained for all other positions of the wedge, the light of both slits being equally increased or diminished as different portions of the wedge are presented to view. But after considerable experience I am convinced a more satisfactory and reliable plan to obtain the actual *constant of absorption* consists in regulating the intensity of a point of light by some such an arrangement as the photometer devised by Captain Abney, and determining the point of extinction on the wedge. In this way not only is the instrument evaluated by the same method as it is used, viz., by a process of extinction, but intensities differing in the ratio of 1 : 32 (or nearly four magnitudes) may easily be obtained, and the accumulation of error referred to above effectually avoided.

I hope nothing I have said will be so misconstrued as to induce the belief that I have any hesitation in accepting the results derived by the aid of a wedge photometer. Far from it; I would call attention particularly to the fact that the observations made with such an instrument are *more* in accordance among themselves than is the case with those made with polarising apparatus. Whether, as I am inclined to believe, and have explained above, the effect of internal reflections, to some extent lawless but yet so significant, is to enter into photometric observations made with polarising apparatus (some positions of the Nicol requiring the *very greatest* care to ensure their effectual elimination), I must leave to be settled by those versed in the use of such instruments; but the difference between the results of Dr. Wolff and Professor Pickering * will be recalled by all. What I do suggest, however, is that there is the possibility of introducing

* *Annals of Harvard Observatory*, vol. xiv.

a systematic error in observations made with a wedge where the error, arising from the coefficient of absorption, *is cumulative in its character*; but—and this, I submit, is a matter of great importance—this systematic error is of a character which can be removed, as I have pointed out, *not* by any comparison with observations of the same kind by other authorities, and the possible introduction thereby of a fresh source of error, but by a strictly independent and scientific investigation, with some form of photometer such as that devised by Captain Abney.

Ivy House, Clapham Common.

On a Method of Obtaining the Error of a Chronometer by Equal Altitudes of two Stars on Opposite Sides of Meridian. By A. Mostyn Field, Commander R.N.

The principle of this method depends upon the sidereal time of passing the meridian of a place, by an imaginary star, having the mean right ascension of the two stars selected, being compared with the time shown by a sidereal chronometer at that instant; the difference is its error on sidereal time. A mean solar chronometer can be used equally well. The sidereal time required is the mean of the right ascensions of the two selected stars. The chronometer time (either mean or sidereal) at that instant is the mean of the times at which the eastern and western stars had equal altitudes, with the "equation of equal altitudes" applied with its proper sign.

Equation of Equal Altitudes.

The rigorous expression, according to Chauvenet, is :—

$$\sin \alpha = \cot \tfrac{1}{2} \text{E.T.} \tan d \tan \delta \cos \alpha - \operatorname{cosec} \tfrac{1}{2} \text{E.T.} \tan l \tan \delta,$$

where

α = equation of equal altitudes $= \dfrac{h - h'}{2}$,

$\tfrac{1}{2}$ E.T. = $\tfrac{1}{2}$ elapsed time $= \dfrac{h + h'}{2}$.

d = declination at upper meridian passage.

$d - \delta$ = declination at observation E. of meridian.

$d + \delta$ = declination at observation W. of meridian.

$\delta = \tfrac{1}{2}$ difference of the declinations at the two times of observation.

h and h' = hour angles from noon at east and west observations respectively.

In the case of equal altitudes of two stars, one east and the other west of meridian, the above formula is strictly accurate whatever may be the difference in the declinations; the half elapsed time being found as follows :—

$$\frac{1}{2}\text{E.T.} = \frac{h+h'}{2},$$
$$= \frac{(R-S)+(S'-R')}{2},$$
$$= \frac{(R-R')+(S'-S)}{2}.$$

Where,

R and R′ = right ascensions of star E. and star W.,

S and S′ = sidereal time of observation of star E. and star W. respectively.

S′ − S, the difference of the sidereal times, may be taken as equal to the difference of times (as shown by a sidereal chronometer) of the observations of the two stars, the chronometer being of course corrected for rate.

If R′ > R, add 24^h to R.

If the western star be observed first, in which case

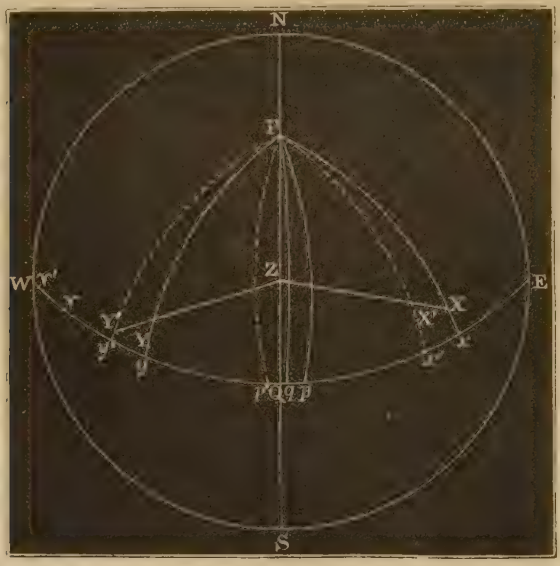
S > S′, then S and S′ are treated algebraically.

d = the mean of the declinations of the two stars.

δ = ½ difference of the declinations of the two stars.

In working the rigorous expression, an approximate value for a is first obtained, disregarding the term cos a, and then rework, using the value of a thus found.

Determination of Sign of "Equation of Equal Altitude."



The above figure is drawn to illustrate the ordinary cases which would occur in practice, but should the observer be in a high latitude, and select stars on the other side of the "six o'clock hour circle" than that shown above, the

following investigation of the sign of "equation of equal altitude" holds good also, and is unchanged.

When $\frac{1}{2}$ E. T. exceeds 6^h, the only changes of sign which occur are those in Chauvenet's formula.

In the accompanying figure, drawn on the plane of the horizon,

Let X and X′ be positions of eastern star at 1st and 2nd observations,

Y and Y′ be positions of western star at 1st and 2nd observations,

ϒ and ϒ′ be positions of 1st p^t. of *Aries* at 1st and 2nd observations,

and let PX be less than PY.

Bisect angle XPY by hour-circle Pp.

Then, any imaginary star on Pp will have for right ascension the mean of the right ascension of X and Y.

Again, bisect angle X′PY′ by hour-circle Pp'.

Then, any imaginary star on Pp' will have for right ascension the mean of the right ascension of X′ and Y′.

Since the right ascensions of X and Y do not change *appreciably* in a few hours, we may assume that Pp and Pp' pass over the *same imaginary star*.

Bisect pPp' by the hour-circle Pq.

Then Pq can be shown to bisect XPY′.

That is qPQ or qQ is the "equation of equal altitude."

Now, if C and C′ be the chronometer times (mean or sidereal) of observation,

$$\text{Mid. time by chronometer} = \frac{C' + C}{2} = \text{time by chronometer, when the "imaginary star" is on the hour-circle P}q.$$

$$\therefore \text{time by chronometer when imaginary star is on meridian PQ} = \text{time by chronometer when it is on hour-circle P}q + \text{arc }Qq,$$

$$= \frac{C' + C}{2} + \text{equation of equal altitudes.}$$

Similarly, when PX is greater than PY,

$$\text{Time by chronometer when imaginary star is on meridian PQ} = \frac{C' + C}{2} - \text{equation of equal altitudes.}$$

Method of Observation.

Select two bright stars, of nearly the same declination, not differing much from the latitude, but differing in R.A. by from 4^h to 8^h.

The mean R.A. is the sidereal time at which the imaginary star referred to above will pass the meridian; therefore the time at which it will be necessary to begin observing will be governed by this, and the observations of one star should be completed shortly before that time, in order to allow an interval to prepare for observing the other.

The sign of the "equation of equal altitudes" remains unaltered, whichever star is first observed.

As a general rule, if the difference in right ascension is less than 6^h, the eastern star should be observed first; if it exceeds 6^h, then the western star; this is in order that the stars may be observed as favourably as possible, with respect to the prime vertical, but it will vary according to the latitude and declination. It will be noticed that if the observations are commenced with the eastern star, then they are, as a whole, taken further from the meridian than in the other case.

If the difference in R.A. exceeds 8^h, then there will probably be an interval between finishing the observations of one star and beginning those of the other, and part of the advantages of the method are lost; the same remark applies if the difference in R.A. is less than 4^h.

Having decided on which star to begin with, observe it continuously in the ordinary way, until the sidereal time is nearly equal to the mean R.A. of the two stars (the error of chronometer on sidereal time should be roughly known), then prepare to observe the other star, commencing at the same altitude as the last observation of the first star, and complete the series, which may be divided into sets, in the usual way.

Owing to the rapid change in "equation of equal altitudes" when there is a large difference in the declinations of the stars, it will be remarked that the "middle times" vary more rapidly than in the case of the Sun; and the rapidity of this change increases as the observations get further away from the sidereal time, at which the "imaginary star" passes the meridian.

If a mean solar chronometer be used, the chronometric interval (corrected for rate) must be turned into a sidereal interval, and the resulting "error of chronometer" will be the error on sidereal time at that particular instant, from which the error on mean time can be readily deduced.

Advantages.

1. The advantages and strength of the equal altitude method are retained, but without the inconvenience of having to wait some hours between the eastern and western observations.

2. There is less time for the chronometer to change its rate.

3. Atmospheric conditions for both eastern and western stars are more likely to be the same than after an interval of some hours.

4. Simplicity of computation; the only logarithms which change being those of cot and cosec $\frac{1}{2}$ E. T.

5. On account of the shorter interval, there is a greater probability of being able to obtain the second half of the series.

Northampton:
1890 *February* 7.

Further Note, with a Correction, on the Spectrum of the Sun-spot of June 1889. By the Rev. A. L. Cortie, S.J.

(*Communicated by E. W. Maunder.*)

In a former note on the spectrum of this important spot (*Monthly Notices*, vol. l., No. 2), the behaviour of the calcium lines in the region B to D was discussed. A comparison was also made with some calcium lines, in a list of bright lines, seen in a metallic prominence over the same spot, by Professor Spörer, of Potsdam, on June 28. A revised list was subsequently published by Professor Vogel (*Nature*, January 9, 1890), from which the calcium lines 6726·5, 6717·16, 6492·41 have been eliminated, and a line of iron (6677·6) and one of barium (6496·31) in the region under discussion have been substituted. A corresponding correction must, therefore, be made in the column headed "Prominence, June 28," of the table appended to my former note (*loc. cit.*, p. 65). Both these lines occur in Young's list of chromospheric lines. In the spot the iron line was widened 0·6 when observed on June 24, and the barium line, the widening of which is difficult to estimate on account of the surrounding telluric haze, was but slightly widened, if at all. The following remarks, in addition to those already published, contain the most noteworthy points with regard to the spectrum of the spot:—

1. The general absorption was dark, and the total number of lines observed as widened, or otherwise affected in the spot, was about two hundred and ten.

2. Of these the most widened lines included, besides calcium lines, lines of iron, titanium, and sodium. Barium and manganese were not much affected in the spot, nor was nickel, except the line between the D lines, which on June 20 was less dark over the spot, and on the 24th and 26th was not widened at all. The proportion of metallic lines among the most widened lines was greater than at the maximum Sun-spot epoch.

3. The most widened of all the metallic lines was the iron line 6148·28, which seemed to be surrounded by a broad and fuzzy band. Estimated widening, 5·0. This is one of Young's bright lines. Ångström draws it much darker than I see it.

4. Many faint lines were among the most widened lines. Among these were the lines 6039·4 (Fievez), 6053·28, and 6061·7 (F), lines which appear in this class, both in maximum and minimum spots. Also the doubles 6243·49, 42·60; and 6240·51, 39·42; which were either considerably widened on the more refrangible side, or displaced to the violet. The line 6305 (F) widened 3·0, was of the same breadth throughout over the spot, showing a steep-sided spot, and yet other lines were unmistakably of the usual spindle shape where widened.

5. A faint line 6209·3 was seen only over the spot, widened 5·0. This line is in Ångström's map, but neither in his nor Burton's catalogue; nor does it appear in the maps of Kirchhoff, Smyth, or Fievez. It was seen in the spectra of Sun-spots, always much widened, in 1884–5–6, at Stonyhurst. It was not seen in that of May 6, 1889. A careful search was made for the line on May 21, but it could not be detected. It reappears in the June spot.

6. A few faint lines were obliterated where they crossed the spot, none of them metallic lines.

7. The following table exhibits the results for the "basic" lines:—

Wave-length.	Elements.	Mean Widening.	Remarks.
*†6064·70	Fe + Ti	0·5	
*†6101·92	Ca + Li	0·7	
*†6121·34	Ca + Co	0·8	
†6154·41	Na + Fe	2·0	
6255·51	Fe + Ti	0·9	
*6346·34	Ru + Ir	0·3	
*†6392·87	Fe + Sb	0·6	
†6407·38	Fe + Sr	0·5	
†6438·35	Ca + Cd	1·2	
†6449·29	Ca + Ba	1·2	
*†6461·98	Fe + Ca	1·2	Bright in prominence June 28.

On the Proper Motion of Groombridge 1830.

By W. T. Lynn, B.A.

It is now nearly fifty years since the large proper motion of *Groombridge* 1830 was detected by Argelander. In the *Monthly Notices* for June 1870 (vol. xxx., p. 203), I put together the results of the observations which had been obtained at the Royal Observatory, Greenwich, of this star, taking the places from the successive great catalogues from the twelve-year (epoch 1845) to the second seven-year (epoch 1864), which was then passing through the press under my own immediate superintendence. Perhaps it may be acceptable if I now complete this by adding the results from the catalogues (the nine-year for 1872, and the ten-year for 1880), which have been since published. It will be noticed that no fewer than 90 observations in R.A. and 100 in N.P.D. have been made at Greenwich of this remarkable

* Bright in chromosphere, Young.
† Resolved either by Liveing and Dewar, or by Fievez.

star, and that the interval between the adopted epochs of the first and last of all these catalogues amounts to 35 years.

Positions of Groombridge 1830.

Epoch.	R.A.	No. of Obs.	N.P.D.	No. of Obs.	Authority.
	h m s		° ′ ″		
1845	11 44 1·53	13	51 10 10·90	10	12-year catalogue.
1850	11 44 19·04	17	51 12 20·04	19	6-year catalogue.
1860	11 44 53·91	18	51 16 37·44	18*	7-year catalogue (1860).
1864	11 45 7·83	8	51 18 21·22	8	7-year catalogue (1864).
1872	11 45 35·68	26	51 21 47·05	31	9-year catalogue.
1880	11 46 3·53	8	51 25 13·92	14	10-year catalogue.

From these we obtain the following mean annual variations for the years comprised between each successive epoch :—

Years.	Ann. Var. in R.A.	Ann. Var. in N.P.D.
	s	″
1845–1850	+3·502	+25·85
1850–1860	3·487	25·74
1860–1864	3·480	25·94
1864–1872	3·481	25·73
1872–1880	+3·481	+25·86

Deducting from these the annual precession, amounting to $+3^{s}\cdot144$ (diminishing to $3^{s}\cdot138$) in R.A., and $+20''\cdot01$ in N.P.D., the following will be the values of the proper motion deducible from these observations :—

Years.	Proper Motion in R.A.	Proper Motion in N.P.D.
	s	″
1845–1850	+0·358	+5·82
1850–1860	0·344	5·73
1860–1864	0·338	5·93
1864–1872	0·341	5·72
1872–1880	+0·343	+5·85

Blackheath :
1890 *January* 29.

* By a misprint this appears as 8 in my former paper.

Observations of Comet 1888 (*Barnard, Sept.* 2), *made at Sydney Observatory with the* 11½*-inch Equatoreal and Filar Micrometer.*

(*Communicated by H. C. Russell, B.A., F.R.S., Government Astronomer.*)

Date.	Sydney M.T.	Star.	Comp.	Comet − Star ΔR.A.	Comet − Star ΔN.P.D.	Comet's Apparent R.A.	Comet's Apparent N.P.D.	Log. $p\Delta$ for R.A.	Log. $p\Delta$ for N.P.D.
1889.	h m s			m s	′ ″	h m s	° ′ ″		
Aug. 13	7 20 43	1	10	+4 37·24	− 6 19·7	19 19 16·47	95 30 55·0	9·478$_n$	0·635
19	8 0 49	2	10	−4 41·90	+10 56·8	19 4 45·77	96 25 22·1	9·184$_n$	0·612

Mean Places of the Comparison Stars for 1889·0.

Star.	R.A. 1889·0.	Reduction.	N.P.D. 1889·0.	Reduction.	Authority.
	h m s	s	° ′ ″	″	
1	19 14 37·13	+2·10	95 37 23·3	−8·6	Radcliffe 2nd Cat. 1844, Yarnall 8255.
2	19 9 25·62	+2·05	96 14 33·9	−8·6	Lalande 36137.

The foregoing late observations may perhaps be useful in checking the orbit of the comet; they were made by Mr. J. A. Pollock.

Sydney Observatory:
1889 *December* 31.

Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the Year 1889. By John Tebbutt.

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation. h m s	Mean Time of Nautical Almanac. h m s
1889.							
May 9	I.	Ecl. D.	Last seen	8-inch	75	1 0 31	1 0 2
21	III.	,,	Began to fade	,,	,,	5 52 52	5 57 30
21	III.	,,	Last seen	,,	,,	5 59 58	
June 1	I.	Tr. Ingr.	Ext. contact	,,	130	22 47 8	22 49
1	I.	,,	Bisection	,,	,,	22 49 5	
1	I.	,,	Int. contact	,,	,,	22 51 34	
2	I.	Tr. Egr.	Int. contact	,,	,,	0 59 53	1 6
2	I.	,,	Bisection	,,	,,	1 1 38	
2	I.	,,	Ext. contact	,,	,,	1 4 22	
2	I.	Occ. R.	Bisection	$4\frac{1}{2}$-inch	90	22 24 17	22 24
2	I.	,,	Last contact	,,	,,	22 26 17	
9	I.	Ecl. D.	Began to fade	,,	,,	21 29 18	21 33 4
9	I.	,,	Last seen	,,	,,	21 33 26	

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation.	Mean Time of Nautical Almanac.
1889.						h m s	h m s
June 10	I.	Occ. R.	Last contact	8-inch	130	0 9 26	0 8
10	I.	Tr. Egr.	Int. contact	$4\frac{1}{2}$-inch	90	21 9 35	
10	I.	,,	Bisection	,,	,,	21 12 20	21 16
10	I.	,,	Ext. contact	,,	,,	21 14 59	
12	II.	Tr. Ingr.	Ext. contact	8-inch	110	21 36 38	
12	II.	,,	Bisection	,,	,,	21 39 7	21 40
12	II.	,,	Int. contact	,,	,,	21 42 22	
13	II.	Tr. Egr.	Int. contact	,,	75	0 12 22	
13	II.	,,	Bisection	,,	,,	0 16 41	0 19
13	II.	,,	Ext. contact	,,	,,	0 20 10	
16	I.	Ecl. D.	Began to fade	,,	,,	23 24 44	23 27 18
16	I.	,,	Last seen	,,	,,	23 27 44	
17	I.	Tr. Egr.	Int. contact	,,	,,	22 52 53	
17	I.	,,	Bisection	,,	,,	22 55 47	22 59
17	I.	,,	Ext. contact	,,	,,	22 59 32	
21	IV.	Tr. Ingr.	Ext. contact	,,	110	0 19 59	0 46

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation.	Mean Time of Nautical Almanac.
1889.						h m s	h m s
June 21	IV.	Tr. Egr.	Ext. contact	8-inch	110	1 7 51	1 0
24	I.	Tr. Ingr.	Ext. contact	,,	70	22 22 58	
24	I.	,,	Bisection	,,	,,	22 25 33	22 26
24	I.	,,	Int. contact	,,	,,	22 29 27	
25	I.	Occ. R.	Last contact	,,	,,	22 6 30	
28	II.	Occ. D.	First contact	$4\frac{1}{2}$-inch	90	20 11 1	
28	II.	,,	Bisection	,,	,,	20 14 20	20 15
28	II.	,,	Last seen	,,	,,	20 16 0	
28	II.	Ecl. R.	First seen	8-inch	70	23 5 29	23 5 17
28	II.	,,	Full brightness	,,	,,	23 7 26	
July 6	III.	Tr. Egr.	Int. contact	,,	,,	21 2 42	
6	III.	,,	Bisection	,,	,,	21 6 57	21 13
6	III.	,,	Ext. contact	,,	,,	21 13 11	
9	I.	Occ. D.	First contact	,,	,,	23 11 8	
9	I.	,,	Bisection	,,	,,	23 13 47	23 14
9	I.	,,	Last seen	,,	,,	23 15 47	

Day of Obs.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	Greenwich Mean Time of Observation.	Mean Time of Nautical Almanac.
1889.						h m s	h m s
July 13	III.	Tr. Ingr.	Ext. contact	8-inch	70	21 32 52	
13	III.	,,	Bisection	,,	,,	21 38 21	21 39
13	III.	,,	Int. contact	,,	,,	21 44 10	
14	III.	Tr. Egr.	Int. contact	,,	,,	0 19 4	
14	III.	,,	Bisection	,,	,,	0 25 3	0 32
14	III.	,,	Ext. contact	,,	,,	0 31 47	
Sept. 5	III.	Ecl. R.	First seen	,,	75	20 37 30	
5	III.	,,	Full brightness	,,	,,	20 43 15	20 39 55
12	III.	Ecl. D.	Last seen	,,	,,	21 44 18	21 43 4
25	I.	Ecl. R.	First seen	,,	,,	22 55 31	
25	I.	,,	Full brightness	,,	,,	22 58 11	22 55 41
30	II.	Tr. Ingr.	Ext. contact	,,	110	22 44 40	
30	II.	,,	Bisection	,,	,,	22 46 5	22 39
30	II.	,,	Int. contact	,,	,,	22 48 9	

Remarks.

May 9.—Unsatisfactory observation through thin cloud. Planet free from cloud 20 seconds subsequently, but satellite not then visible.

May 21.—Sky beautifully clear, but Moon in last quarter. Slight tremor of images at moment of final disappearance.

June 1, 2.—Fair definition at ingress, and better at egress. Planet low, and boiling at occultation phase.

June 9.—Images steady and well defined. Sky clear and observation good.

June 10.—Definition pretty good at the occultation phase and at the first two phases of the transit egress. Image very much disturbed at the external contact.

June 12, 13.—Definition bad and observations unsatisfactory.

June 16, 17.—Sky beautifully clear. Images steady and well defined at the eclipse, but the Moon had risen. Images rather tremulous at transit egress.

June 21.—Good definition, but observation very difficult. No internal contact occurred.

June 24.—Steadiness and definition satisfactory.

June 25.—Good definition, but observed time rather late. The reappearance from eclipse could not be observed.

June 28.—Sky beautifully clear. Planet low and badly defined at the occultation. Definition good for the eclipse.

July 6.—Images steady and well defined, but power not sufficiently high for satisfactory observation.

July 9.—Images steady and well defined. Good observation.

July 13, 14.—Definitions unusually good at both ingress and egress. The satellite crossed a portion of the planet's disc as a dark spot.

Sept. 5.—Sky clear about the planet. The first recorded time is probably 10 or 15 seconds late.

Sept. 12.—Sky beautifully clear, and definition good.

Sept. 25.—Sky clear, but images tremulous and badly defined.

Sept. 30.—Images steady and definition good. There is a considerable discrepancy between the computed and observed times.

Note.—No occulting bar has been employed in the eclipse observations. The times given in the first and seventh columns are the Windsor mean times of observation diminished by $10^h\ 3^m\ 20^s{\cdot}5$ and entered to the nearest second.

Windsor, N.S. Wales:
1889 *December* 27.

Ephemeris for Physical Observations

Greenwich Noon	Angle of Position of ♃'s Axis.		Latitude of Earth | Sun above ♃'s Equator.		Annual Parallax.	Longitude of ♃'s Central Meridian. (877°·90)	(870°·27)	Corr. for Phase.
	P	L−O.	B	R	A−L.	I.	II.	
1890	°	°	°	°	°	°	°	°
Mar. 23	343·946	170·226	−0·780	−1·006	− 9·410	229·38	130·72	+0·39
28	343·646	171·081	·739	0·985	9·839	298·37	161·56	·42
Apr. 2	343·366	171·890	·699	·963	10·221	7·42	192·46	·45
7	343·106	172·650	·660	·941	10·554	76·53	223·42	·48
12	342·867	173·358	·622	·919	10·835	145·71	254·44	·51
17	342·649	174·010	·585	·898	11·060	214·95	285·53	·53
22	342·453	174·602	·549	·876	11·225	284·26	316·68	·55
27	342·280	175·131	·515	·854	11·326	353·63	347·90	·56
May 2	342·129	175·595	−0·483	−0·832	−11·361	63·07	19·19	+0·56
7	342·001	175·990	·453	·810	11·327	132·57	50·54	·56
12	341·897	176·313	·424	·787	11·221	202·15	81·96	·55
17	341·817	176·561	·397	·765	11·040	271·80	113·45	·53
22	341·762	176·733	·373	·743	10·782	341·51	145·02	·51
27	341·731	176·826	·352	·720	10·445	51·29	176·65	·48
June 1	341·724	176·840	−0·333	−0·698	−10·029	121·14	208·34	+0·44
6	341·743	176·774	·316	·675	9·534	191·05	240·09	·40
11	341·786	176·630	·302	·653	8·959	261·02	271·91	·35
16	341·854	176·408	·291	·630	8·305	331·05	303·79	·30
21	341·946	176·111	·283	·608	7·577	41·12	335·71	·25
26	342·061	175·743	·277	·585	6·778	111·24	7·68	·20
July 1	342·198	175·310	−0·274	−0·562	− 5·914	181·40	39·69	+0·15
6	342·355	174·818	·274	·559	4·990	251·59	71·72	·11
11	342·531	174·275	·277	·517	4·014	321·80	103·78	·07
16	342·723	173·689	·281	·494	2·996	32·01	135·84	·04
21	342·927	173·071	·288	·471	1·945	102·22	167·90	+0·02
26	343·142	172·432	·297	·448	− 0·873	172·41	199·94	·00
31	343·362	171·784	·307	·425	+ 0·210	242·58	231·95	·00
Aug. 5	343·584	171·137	−0·318	−0·402	+ 1·291	312·71	263·93	−0·01
10	343·804	170·504	·331	·379	2·357	22·78	295·86	·02
15	344·018	169·896	·344	·356	3·399	92·79	327·72	·05
20	344·221	169·324	·357	·332	4·406	162·73	359·51	·08
25	344·409	168·798	·370	·309	5·366	232·59	31·22	·13
30	344·579	168·328	·382	·286	6·272	302·37	62·85	·17
Sept. 4	344·727	167·920	−0·394	−0·263	+ 7·116	12·05	94·38	−0·22

of Jupiter, 1890. By A. Marth.

Greenwich Noon. 1890.	Apparent Diam. Equat.	Apparent Diam. Polar.	Difference of limbs in A.R.	Difference of limbs in Decl.	Defect of illumination. Equat.	Defect of illumination. in A.R.	Defect of illumination. in Decl.	d	w
	″	″	s	″	″	s	″	°	°
Mar. 23	34·92	32·70	2·454	32·87	0·23	0·016	0·02	9·41	271·55
28	35·35	33·11	2·481	33·29	·26	·017	·02	9·84	·60
Apr. 2	35·82	33·54	2·510	33·73	·28	·019	·02	10·22	·65
7	36·31	34·00	2·541	34·20	·31	·020	·02	10·56	·70
12	36·82	34·48	2·575	34·69	·33	·022	·02	10·84	·74
17	37·37	34·99	2·610	35·21	·35	·023	·03	11·06	·79
22	37·94	35·52	2·647	35·75	·36	·024	·03	11·23	·85
27	38·53	36·07	2·686	36·31	·37	·024	·03	11·33	·90
May 2	39·14	36·65	2·727	36·89	0·38	0·025	0·03	11·37	·94
7	39·77	37·24	2·769	37·49	·39	·025	·03	11·33	271·99
12	40·42	37·84	2·813	38·10	·39	·025	·03	11·23	272·04
17	41·08	38·46	2·858	38·72	·38	·025	·03	11·05	·09
22	41·74	39·08	2·903	39·35	·37	·024	·03	10·79	·14
27	42·41	39·71	2·949	39·98	·36	·023	·03	10·45	·20
June 1	43·08	40·33	2·996	40·61	0·33	0·021	0·03	10·04	·27
6	43·73	40·94	3·042	41·23	·30	·020	·02	9·55	·34
11	44·37	41·54	3·088	41·83	·27	·018	·02	8·97	·43
16	44·98	42·12	3·132	41·91	·24	·015	·02	8·31	·55
21	45·56	42·66	3·174	42·95	·20	·013	·02	7·58	·70
26	46·10	43·16	3·214	43·45	·16	·011	·01	6·79	272·85
July 1	46·59	43·62	3·251	43·91	0·12	0·008	0·01	5·92	273·00
6	47·02	44·02	3·284	44·31	·09	·006	·01	4·99	273·3
11	47·38	44·36	3·313	44·65	·06	·004	·00	4·02	273·7
16	47·67	44·63	3·337	44·91	·03	·002	...	3·00	274·4
21	47·88	44·83	3·356	45·10	·01	·000	...	1·95	275·7
26	48·00	44·95	3·369	45·21	...	...	...	0·89	280·5
31	48·05	44·99	3·375	45·24	...	...	...	0·24	59·0
Aug. 5	48·00	44·94	3·376	45·19	0·01	0·000	...	1·29	86·1
10	47·86	44·81	3·371	45·06	·02	·001	...	2·36	88·8
15	47·65	44·61	3·359	44·85	·04	·003	·00	3·40	89·7
20	47·35	44·33	3·341	44·56	·07	·005	·01	4·41	90·3
25	46·98	43·99	3·318	44·21	·10	·007	·01	5·37	90·7
30	46·54	43·58	3·290	43·80	·14	·009	·01	6·27	90·9
Sept. 4	46·05	43·12	3·258	43·33	0·18	0·012	0·01	7·12	91·1

Greenwich Noon.	Angle of Position of ♃'s Axis.		Latitude of Earth | Sun above ♃'s Equator.		Annual Parallax.	Longitude of ♃'s Central Meridian (877°·90)	Longitude of ♃'s Central Meridian (870°·27)	Corr. for Phase.
	P	L−O.	B	R	A−L.	I.	II.	
1890.	°	°	°	°	°	°	°	°
Sept. 9	344·851	167·581	−0·404	−0·240	+7·891	81·63	125·82	−0·27
14	344·949	167·316	·413	·216	8·592	151·11	157·16	·32
19	345·018	167·129	·421	·193	9·215	220·49	188·39	·37
24	345·057	167·023	·426	·170	9·757	289·77	219·52	·41
29	345·066	166·999	·430	·146	10·218	358·95	250·55	·45
Oct. 4	345·045	167·057	−0·432	−0·123	+10·597	68·04	281·49	−0·49
9	344·994	167·196	·431	·099	10·895	137·03	312·33	·52
14	344·913	167·416	·428	·076	11·112	205·93	343·08	·54
19	344·803	167·715	·423	·052	11·251	274·74	13·75	·55
24	344·666	168·091	·415	·029	11·314	343·47	44·34	·56
29	344·504	168·540	·405	−0·005	11·303	52·13	74·85	·56
Nov. 3	344·317	169·059	−0·392	+0·018	+11·223	120 72	105·30	−0·55
8	344·108	169·644	·377	·042	11·077	189·25	135·68	·53
13	343 879	170·293	·359	·065	10·867	257·72	166·00	·51
18	343·631	171·003	·339	·089	10·597	326·14	196·27	·49
23	343·367	171·769	·317	·112	10·271	34·51	226·49	·46
28	343·088	172·586	·292	·136	9·893	102·84	256·67	·43
Dec. 3	342·797	173·452	−0·265	+0·159	+9·467	171·13	286·82	−0·39
8	342·496	174·364	·236	·183	8·996	239·40	316 94	·35
13	342·186	175·318	·205	·207	8·483	307·64	317·04	·31
18	341·870	176·309	−0·171	+0·230	+7·933	15·86	17·11	−0·27

The angle L−O+180° is the Jovicentric longitude of the Earth, reckoned in the plane of *Jupiter's* equator from O, the point of the vernal equinox of *Jupiter's* northern hemisphere or the point of the ascending node of the planet's orbit on its equator. The angle A−O+180° is the corresponding longitude of the Sun, or A−L the difference between the two longitudes. The two values of the "longitude of ♃'s central meridian," given for each date, depend on the elements adopted in the ephemeris for 1889. As observations of the white spots in the neighbourhood of the planet's equator, which may have been made during the last opposition, have not yet reached me, I do not know how far the adopted daily rate 877°·90 of system I. represents their present motion, and must content myself with referring to the comparison of preceding observations given on p. 94 of vol. xlix. Some observations of the remnant of the great reddish spot, kindly communicated by Mr. Denning, show that the spot preceded last year the adopted zero-meridian of system II. about six or seven minutes, so that in case the indicated acceleration of its motion has meanwhile been main-

Greenwich Noon.	Apparent Diam. Equat.	Apparent Diam. Polar.	Difference of limbs in A.R.	Difference of limbs in Decl.	Defect of illumination. Equat.	Defect of illumination. in A.R.	Defect of illumination. in Decl.	d	w
1890.	″	″	s	″	″	s	″	°	°
Sept. 9	45·51	42·61	3·222	42·82	0·22	0·014	0·01	7·89	91·25
14	44·93	42·06	3·182	42·27	·25	·017	·02	8·59	91·37
19	44·32	41·49	3·139	41·69	·29	·019	·02	9·22	91·48
24	43·68	40·90	3·095	41·09	·32	·021	·02	9·76	91·58
29	43·03	40·29	3·049	40·48	·34	·023	·02	10·22	91·67
Oct. 4	42·37	39·67	3·002	39·86	0·36	0·024	0·02	10·60	91·78
9	41·71	39·05	2·954	39·24	·38	·025	·02	10·90	91·86
14	41·06	38·44	2·906	38·63	·38	·026	·02	11·12	91·93
19	40·41	37·83	2·859	38·02	·39	·026	·02	11·26	91·99
24	39·78	37·24	2·813	37·43	·39	·026	·02	11·32	92·06
29	39·16	36·66	2·767	36·85	·38	·026	·02	11·31	92·13
Nov. 3	38·56	36·10	2·722	36·29	0·37	0·025	0·02	11·23	92·20
8	37·99	35·57	2·679	35·76	·35	·024	·02	11·09	92·28
13	37·44	35·06	2·637	35·25	·34	·023	·02	10·88	92·36
18	36·92	34·57	2·597	34·76	·32	·021	·02	10·61	92·45
23	36·43	34·11	2·559	34·30	·29	·020	·02	10·28	92·54
28	35·96	33·67	2·523	33·87	·27	·018	·02	9·90	92·63
Dec. 3	35·53	33·26	2·489	33·47	0·24	0·016	0·02	9·48	92·73
8	35·12	32·88	2·456	33·09	·22	·014	·01	9·01	92·84
13	34·74	32·53	2·425	32·74	·19	·013	·01	8·49	92·96
18	34·39	32·20	2·397	32·42	·16	·011	·01	7·94	93·09

tained or increased, the difference may now be considerably greater.—The differences of successive values of the longitudes of ♃'s central meridian amount, for the intervals of five days, to twelve rotations in addition to the differences directly deduced, so that, for instance, the differences of the first two values are 4388°·99 and 4350°·84. The addition of the "correction for phase" to the longitudes of the central meridian gives the longitudes of the meridian which bisects the illuminated disc.

The values of the apparent diameters of the disc, &c., depend on the same data as in the ephemerides for preceding years. The formulæ employed may be found in vol. xlv. p. 508. The defects of illumination are before opposition on the preceding side and south, and after opposition on the following side and north.

The following is a list of Greenwich mean times, when the zero meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc. The times of intermediate passages must be found by interpolation, the intervals

between successive passages being $9^h\ 50^m{\cdot}40$ to $50^m{\cdot}67$ in the first system, and $9^h\ 55^m{\cdot}58$ to $55^m{\cdot}85$ in the second.

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
	h m	h m		h m	h m
Mar. 24	18 56·9	22 1·8	April 30	16 44·1	17 40·3
25	14 37·0	17 53·2	May 1	12 25·1	13 31·6
26	20 8·7	23 40·5	2	17 56·6	19 18·7
27	15 49·8	19 31·9	3	13 37·6	15 10·0
28	21 31·5	15 23·4	4	19 9·1	20 57·1
29	17 2·6	21 10·6	5	14 50·1	16 48·4
30	22 34·3	17 2·1	6	20 21·6	12 39·8
31	18 15·4	22 49·3	7	16 2·6	18 26·8
Apr. 1	13 56·5	18 40·8	8	21 34·1	14 18·1
2	19 28·2	14 32·2	9	17 5·1	20 5·1
3	15 9·3	20 19·4	10	12 56·1	15 56·5
4	20 40·9	16 10·9	11	18 27·5	21 43·5
5	16 22·0	21 58·0	12	14 8·5	17 34·8
6	21 53·7	17 49·5	13	19 40·0	13 26·1
7	17 34·8	13 40·9	14	15 20·9	19 13·1
8	23 6·4	19 28·1	15	20 52·4	15 4·4
9	18 47·5	15 19·5	16	16 33·3	20 51·4
10	14 28·5	21 6·7	17	12 14·3	16 42·7
11	20 0·1	16 58·1	18	17 45·7	12 34·0
12	15 40·2	12 49·5	19	13 26·6	18 21·0
13	21 12·8	18 36·7	20	18 58·1	14 12·3
14	16 53·9	14 28·1	21	14 39·0	19 59·2
15	22 25·5	20 15·2	22	2 41 Shadow of *Sat.*	
16	18 6·5	16 6·6		*IV.* crosses central meridian.	
17	13 47·6	21 53·8	22	20 10·4	15 50·5
18	19 19·2	17 45·2	23	15 51·4	11 41·8
19	15 0·2	13 36·6	24	11 32·3	17 28·7
20	20 31·8	19 23·7	25	17 3·7	13 20·0
21	16 12·8	15 15·1	26	12 44·6	19 6·9
22	21 44·4	21 2·2	27	18 16·0	14 58·2
23	17 25·4	16 53·6	28	13 56·9	20 45·1
24	13 6·4	12 44·9	29	19 28·3	16 36·4
25	18 38·0	18 32·0	30	15 9·2	12 27·7
26	14 19·0	14 23·4	31	20 40·6	18 14·6
27	19 50·5	20 10·5	June 1	16 21·5	14 5·8
28	15 31·6	16 1·8	2	12 2·4	19 52·7
29	21 3·1	21 48·9	3	17 33·8	15 44·0

		I. (877°·90)	II. (870°·27)			I. (877°·90)	II. (870°·27)
		h m	h m			h m	h m
June	4	13 14·7	11 35·2	July	10	15 12·1	11 12·6
	5	18 46·0	17 22·2		11	9 6	Shadow of *S. IV.*
	6	14 26·9	13 13·4			10 52·9	16 59·4
	7	19 58·2	19 0·2		12	16 24·2	12 50·5
		20 48	Shadow of *S. IV.*		13	12 5·0	8 41·7
	8	15 39·1	14 51·5		14	17 36·2	14 28·4
	9	11 20·0	20 38·3		15	13 17·0	10 19·6
	10	16 51·3	16 29·6		16	8 57·8	16 6·4
	11	12 32·2	12 20·8		17	14 29·1	11 57·5
	12	18 3·5	18 7·6		18	10 9·9	17 44·3
	13	13 44·4	13 58·8		19	15 41·1	13 35·4
	14	19 15·7	19 45·7		20	11 21·9	9 26·6
	15	14 56·6	15 36·9		21	16 53·1	15 13·4
	16	10 37·4	11 28·1		22	12 34·0	11 4·5
	17	16 8·7	17 14·9		23	8 14·8	16 51·3
	18	11 49·6	13 6·1		24	13 46·0	12 42·4
	19	17 20·9	18 53·0		25	9 26·8	8 33·6
	20	13 1·7	14 44·2		26	14 58·0	14 20·4
	21	18 33·0	10 35·4		27	10 38·9	10 11·6
	22	14 13·9	16 22·2		28	3 16	Shadow of *S. IV.*
	23	9 54·7	12 13·4			16 10·1	15 58·3
	24	14 57	Shadow of *S. IV.*		29	11 50·9	11 49·5
		15 26·0	18 0·2		30	7 31·7	7 40·7
	25	11 6·8	13 51·4			17 22·1	17 36·3
	26	16 38·1	9 42·6		31	13 4·0	13 27·4
	27	12 18·9	15 29·3	Aug.	1	8 43·8	9 18·6
	28	17 50·2	11 20·5		2	14 15·1	15 5·4
	29	13 31·0	17 7·3		3	9 55·9	10 56·6
	30	9 11·8	12 58·5		4	15 27·1	16 43·4
July	1	14 43·1	8 49·7		5	11 9·0	12 34·5
	2	10 23·9	14 36·4		6	16 39·2	8 25·7
	3	15 55·1	10 27·6		7	12 20·1	14 12·5
	4	11 36·0	16 14·4		8	8 0·9	10 3·7
	5	17 7·2	12 5·6		9	13 32·2	15 50·6
	6	12 48·0	17 52·3		10	9 13·1	11 41 8
	7	8 28·8	13 43·5		11	14 44·4	17 28·6
	8	14 0·1	9 34·7		12	10 25·3	13 19·8
	9	9 40·9	15 21·4		13	15 56·6	9 11·0

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
	h m	h m		h m	h m
Aug. 13	21 27	Shadow of *S. IV.*	Sept. 18	8 8·4	8 53·2
14	11 37·4	14 57·9	19	13 40·0	14 40·3
15	17 8·8	10 49·1	20	9 21·0	10 31·7
16	12 49·6	16 36·0	21	14 52·6	6 23·1
17	8 30·5	12 27·2	22	10 33·7	12 10·3
18	14 1·9	8 18·4	23	6 14·8	8 1·7
19	9 42·8	14 5·3	24	11 46·4	13 48·9
20	15 14·1	9 56·6	25	7 27·5	9 40·3
21	10 55·0	15 43·5	26	12 59·1	15 27·5
22	16 26·4	11 34·7	27	8 40·2	11 18·9
23	12 7·3	7 26·0	28	14 11·9	7 10·4
24	7 48·3	13 12·9	29	9 53·0	12 57·6
25	13 19·6	9 4·2	30	15 24·7	8 49·1
26	9 0·6	14 51·1	Oct. 1	11 5·8	14 36·3
27	14 32·0	10 42·4	2	6 46·9	10 27·8
28	10 12·9	16 29·3	3	4 4	Shadow of *S. IV.*
29	15 44·3	12 20·6		12 18·6	6 19·2
30	11 25·3	8 11·9	4	7 59·7	12 6·5
	15 38	Shadow of *S. IV.*	5	13 31·5	7 58·0
31	7 6·2	13 58·9	6	9 12·6	13 45·2
Sept. 1	12 37·7	9 50·2	7	14 44·3	9 36·7
2	8 18·6	15 37·2	8	10 25·5	5 28·2
3	13 50·1	11 28·5	9	6 6·6	11 15·5
4	9 31·1	7 19·9	10	11 38·4	7 7·0
5	15 2·6	13 6·9	11	7 19·5	12 54·3
6	10 43·5	8 58·2	12	12 51·3	8 45·8
7	6 24·5	14 45·2	13	8 32·5	14 33·1
8	11 56·0	10 36·6	14	14 4·2	10 24·7
9	7 37·1	6 27·9	15	9 45·4	6 16·2
10	13 8·6	12 15·0	16	5 26·6	12 3·5
11	8 49·6	8 6·3	17	10 58·4	7 55·0
12	14 21·1	13 53·4	18	6 39·6	13 42·4
13	10 2·1	9 44·8	19	12 11·4	9 33·9
14	15 33·7	15 31·9		22 17	Shadow of *S. IV.*
15	11 14·7	11 23·3	20	7 52·6	5 25·5
16	6 55·8	7 14·7	21	13 24·4	11 12·8
	9 50	Shadow of *S. IV.*	22	9 5·6	7 4·4
17	12 27·3	13 1·8	23	4 46·8	12 51·7

	I. (877°·90)	II. (870°·27)		I. (877°·90)	II. (870°·27)
	h m	h m		h m	h m
Oct. 24	10 18·6	8 43·3	Nov. 21	7 41·5	11 58·4
25	5 59·9	4 34·9	22	3 22·8	7 50·1
26	11 31·7	10 22·3		10 44 Shadow of *S. IV.*	
27	7 12·9	6 13·9	23	8 54·8	3 41·7
28	12 44·8	12 1·2	24	4 36·1	9 29·2
29	8 26·0	7 52·8	25	10 8·0	5 20·9
30	13 57·9	13 40·2	26	5 49·3	11 8·4
31	9 39·1	9 31·8	27	11 21·3	7 0·1
Nov. 1	5 20·3	5 23·4	28	7 2·6	12 47·6
2	10 52·2	11 10·8	29	12 34·6	8 39·2
3	6 33·5	7 2·4	30	8 15·9	4 30·9
4	12 5·3	12 49·8	Dec. 1	3 57·2	10 18·4
5	7 46·6	8 41·5	2	9 29·2	6 10·1
	16 30 Shadow of *S. IV*		3	5 10·5	11 57·6
6	13 18·5	4 33·1	4	10 42·5	7 49·3
7	8 59·7	10 20·5	5	6 23·8	3 41·0
8	4 41·0	6 12·1	6	11 55·8	9 28·5
9	10 12·9	11 59·6	7	7 37·1	5 20·2
10	5 54·2	7 51·2	8	3 18·4	11 7·7
11	11 26·1	13 38·6	9	4 58 Shadow of *S. IV.*	
12	7 7·4	9 30·3		8 50·4	6 59·4
13	12 39·3	5 21·9	10	4 31·8	12 46·9
14	8 20·6	11 9·4	11	10 3·7	8 38·6
15	13 52·5	7 1·0	12	5 45·1	4 30·3
16	9 33·8	12 48·5	13	11 17·1	10 17·8
17	5 15·1	8 40·1	14	6 58·4	6 9·5
18	10 47·0	4 31·8	15	12 30·4	11 57·0
19	6 28·3	10 19·3	16	8 11·7	7 48·7
20	12 0·2	6 10·9			

The reason why in the list the times are added, when the shadow of *Satellite IV.* crosses the central meridian is: to remind observers of the favourable opportunities, which they may have during the latter part of the present apparition, of contributing by proper measurements of the coordinates of the shadow (and also of the satellite before and after its transits and occultations) to the proper determination of several elements of the orbit, as I have explained in a note published in vol. xliv., p. 241, on the last occasion, when such measurements would have been of special value.

Erratum in NAUTICAL ALMANAC *for* 1890, *p.* 454.

July 11. Transit of shadow of *Jupiter's* fourth Satellite.

	h	m		h	m
For	5	46	and	10	26
Read	6	46	and	11	26